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The Transition to Clean Energy: Liquidity, Information, and Gender

La transition vers une énergie propre : liquidité, information et genre

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This paper looks at the transition to clean energy in low-income countries, focusing on financial constraints, awareness of the health impacts of indoor smoke, and gender roles. Specifically, it discusses three studies that evaluate the effects of a clean fuel subsidy and a health awareness intervention and examine the relationship between clean fuel adoption and women's use of time in India. First, despite subsidies for liquefied petroleum gas (LPG), poor households remain sensitive to LPG prices because of liquidity constraints. The timing of subsidy disbursements therefore plays a crucial role in encouraging LPG adoption among poorer populations. Second, while health information can bring about behavioral changes, its impact is insufficient to drive a meaningful shift to clean energy usage as long as financial barriers remain. Finally, although using clean fuels saves women time, this is not necessarily enough to allow them to take up employment outside the home. The paper concludes with suggestions for future research.

Keywords: Clean fuels, LPG, Subsidy, Health awareness, Women, Time-use, India.

Cet article porte sur la transition vers les énergies propres dans les pays à faible revenu, en mettant l'accent sur les contraintes financières, la sensibilisation aux impacts sanitaires de la fumée domestique et les rôles de genre. Il s'appuie sur trois études évaluant les effets d'une subvention pour les combustibles propres et d'une intervention de sensibilisation à la santé, ainsi que sur l'analyse de la relation entre l'adoption de ces combustibles et l'usage du temps par les femmes en Inde. Premièrement, malgré les subventions au gaz de pétrole liquéfié (GPL), les ménages pauvres restent sensibles au prix du GPL en raison de contraintes de liquidité. Le moment du versement des subventions s'avère donc déterminant pour l'adoption du GPL parmi les populations

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défavorisées. Deuxièmement, bien que l'information sur les risques sanitaires entraîne des changements de comportement, son effet reste insuffisant pour induire une transition profonde vers les énergies propres tant que les contraintes financières persistent. Enfin, le gain de temps que procure l'usage de combustibles propres aux femmes n'est pas nécessairement suffisant pour leur permettre d'accéder à un emploi à l'extérieur du foyer. L'article se conclut par des pistes de recherche futures.

Mots-clés : Combustibles propres, GPL, Subvention, Sensibilisation à la santé, Femmes, Usage du temps, Inde.

JEL codes: D10, H26, O13, O17, I38, I15, J22, Q53.

1. INTRODUCTION

In my talk today, I will first present certain facts that underlie the transition to clean energy in low-income countries: in particular, the role of poverty and financial constraints, awareness of the adverse health effects of inhaling indoor smoke, and the role of gender in facilitating this transition.

Once I have mentioned these facts, I will discuss three studies on this issue with which I have been engaged. The first study aimed to understand whether public transfer programmes that loosen financial constraints are effective in increasing the take-up of clean fuels. Second, if we increase awareness about the adverse health effects of indoor air pollution, what behavioural changes do we see in low-income settings and are these changes effective in making the transition to clean energy? Finally, we ask whether there are substantive changes in the allocation of time by women, who are primarily responsible for domestic work, when we move to modern cooking technology using clean fuels. What is the potential time saving as a result of adopting modern cooking technology and what implications does this have for the household income?

I summarize and conclude with potential issues for future research that some of you may be interested in investigating.

Fuel usage facts in developing countries

It is a well-known fact that a large share of the world's population – almost 4 billion people – lack access to clean energy for cooking. There is a positive relationship between GDP per capita and the adoption of clean fuels for cooking in countries across the world. For example, in sub-Saharan Africa and in South Asia, where there are low levels of adoption of modern energy sources for cooking, there are also high levels of poverty.

What are the implications of using dirty fuels for indoor air quality? Data from a typical North Indian village (Somanathan *et al.*, 2019), which tracks the presence of PM 2.5[1] in a kitchen that uses

[1] Airborne particulate matter (PM) is a mixture of many chemical species. It is a complex mixture of solids and aerosols composed of small droplets of

traditional, solid fuels for cooking over 24 hours, shows two big spikes: one at around six in the morning, and another after about six in the evening. These are the two times at which food is typically cooked in the kitchen. The concentration of PM 2.5 particulate matter at these times goes up to almost 2000 ug/m^3 (micrograms per cubic meter of air), which is 40 times the World Health Organization (WHO) safe limit for PM 2.5. It is clear from these data that wood, cow dung and other solid fuels are extremely polluting because they generate indoor smoke. These household sources are the single largest contributors to the pollution of the ambient air in much of the developing world. Indoor air pollution due to the usage of solid fuels can have very adverse health impacts. For instance, the WHO estimates that, in 2016, 3.8 million premature deaths were attributable to household air pollution, mostly in low- and middle-income countries.

The third well-known fact is that women bear a large burden not just of using, but also of collecting, these dirty fuels for cooking. For example, in South Asia, in countries such as India, Bangladesh and Nepal, women spend 20 or more hours per week collecting biomass fuels. Later, I will show data that we collected, through the detailed measurement of time use, showing that women spend on average almost four hours per day cooking, using these solid fuels.

What alternative technologies to solid fuels are available? The alternatives that are available require a climb up the energy ladder (Figure 1 in Annex). In low-income countries and in situations of extreme poverty, there is a high use of wood, charcoal, coal and other dirty fuels, which are often freely available or cheap. Hence these communities tend to use stoves and traditional cooking methods that are extremely polluting. When nations climb up to middle-income levels but have not yet transitioned all the way to the high-income level, they are likely to have better access to a cleaner fuel, liquefied petroleum gas or LPG. This is the technology that I will be focusing on in terms of a viable energy transition that we can make in middle- and low-income settings. Note that often LPG is not piped to the households, but is available through portable cylinders, which can then be connected to a stove.

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liquid, dry solid fragments, and solid cores with liquid coatings. Fine particulate matter is defined as particles that are 2.5 microns or less in diameter (PM2.5). Therefore, PM2.5 comprises a portion of PM10.

You might worry about the fact that LPG is also potentially polluting because it is sourced from a fossil fuel. Making the transition to full, last-mile electrification, which is the ultimate goal of clean energy transition, is extremely demanding in terms of infrastructure requirements and is prohibitively costly for most low-income countries. Moreover, if the electricity is generated by burning coal, electrification does not entail a transition to clean energy. For example, in the Indian context, 80% of electricity generation is coal-based.

Would it be quicker to switch to more efficient and less polluting cooking stoves that use solid fuels rather than to try to shift away from solid fuels themselves? Unfortunately, attempts to increase the usage of efficient cooking stoves have not been very successful, due to low adoption rates and the inconvenience of using these efficient stoves.

To summarize, the focus of this discussion will be on the demand side constraints to clean energy transition in low-income settings, and we will investigate the following questions:

(1) Can public subsidies help address the poverty and financial constraints faced by households in adopting clean cooking technology?
(2) What is the role of health awareness in changing the behaviour of low-income households in relation to the use of solid fuels?
(3) Do traditional gender roles constrain the take-up of clean cooking technologies? If so, how can we loosen these constraints on the adoption and use of clean fuel?

I will discuss each of these issues with reference to three research papers that focus on India.

2. LOOSENING FINANCIAL CONSTRAINTS: FUEL SUBSIDY PROGRAMME

In India, we had a universal LPG subsidy programme for several years until 2020. Under this programme the out-of-pocket expenditure on an LPG cylinder was lowered by almost 50%. Despite this universal subsidy, it was primarily richer households which were taking up LPG for cooking and moving away from solid fuels. In 2016, therefore, the Indian government launched one of the largest clean energy subsidy

programmes in the world, called the PMUY (Prime Minister's Ujjwala Yojana) programme. This programme subsidized the start-up costs of shifting from solid fuel cooking to LPG stoves for low-income households, and brought in a universal subsidy on refills of LPG cylinders.

The PMUY has been a huge success – 72 million households had access to LPG as of 2019. However, these households do not use LPG regularly for cooking. That is, these households might use LPG sometimes, but most of the time they use solid fuels for cooking. Thus, they engage in mixed fuel cooking, as a result of which the rate of LPG cylinder refills is very low. While the maximum annual usage by a four-member household would be about 12 bottles or 12 cylinders if the only fuel used by the household was LPG, the data show that the average annual usage is only about three LPG cylinder refills. Hence India is nowhere near eliminating the usage of solid fuels.

Why is this the case, despite the presence of a substantive LPG refill subsidy programme? Let us first understand the functioning of the subsidy programme up to 2020 (see Figure 2). This subsidy programme worked as a cashback scheme – when an individual went to the LPG dealer/shop to buy an LPG cylinder refill, they paid the market price. This was the upfront, or over-the-counter, price for the LPG refill. The subsidy was transferred into their LPG consumer linked bank account about seven days after this purchase. Thus, the subsidy was not provided at the point of purchase but was made a few days after the purchase. Since the cashback subsidy amount moved in tandem with the LPG refill market price, the out-of-pocket (or post-subsidy) cost of the LPG refill was more or less fixed, as shown in Figure 3. Theoretically, therefore, as a result of this subsidy programme consumers should have been insensitive to changes in the over-the-counter (market) price because their out-of-pocket expenditure did not vary.

We analysed administrative data on the consumption of LPG refills for about one million LPG customers in central India, along with detailed household survey data on a sub-sample of almost 3,000 rural households, between 2017 and 2019. Our findings highlight the key role of fluctuations in households' liquidity or liquidity constraints in the sensitivity of these households to the LPG refill market prices, in spite of the fact that, because of the LPG subsidy, the amount that they had to pay net of the subsidy remained constant (Afridi *et al.*, 2021).

Our data came from central India, and from one of the poorer states of the country (Madhya Pradesh). The main outcome of interest is how many refills of LPG the household purchased each month in a particular year as a function of the variation in the log of the per unit LPG market price (as well as the subsidy amount). Our indicator of relative poverty was whether the household was a PMUY beneficiary or not. We also controlled for non-observable variables at the monthly level and household level, and for any annual trends in the take-up of LPG refills. It should be noted that in India the market price of LPG is determined exogenously, since India is almost completely dependent on the international market for the supply of petroleum products. Hence, we interpreted the coefficient on the market price as the causal effect of fluctuations in the over-the-counter LPG refill price on LPG refill consumption.

Unlike our theoretical prediction, we found extreme sensitivity of poor (PMUY) households to variations in the LPG refill market price, despite the fact that the net out-of-pocket payment was constant. So, a 1% increase in the over-the-counter refill price led to an approximate 1.4% decrease in the LPG refill purchase by these households.

We also matched the administrative data to the detailed household survey data for a random sub-sample of rural LPG customers. We found similar results: a 1% change in the refill price led to a 1% decline in the LPG refill cylinder demand. At the same time, we observed an increase in the usage of wood, cow dung and other biomass fuels when the LPG refill market price went up, in spite of the fact that the out-of-pocket price remained constant. A 1% increase in the refill price led to a 5% increase in the monthly solid fuel expenditure of PMUY households.

Next, we used the National Family Health Survey or DHS data for India to obtain detailed information on the pregnancy timing, child health, birth weight, neonatal mortality, and incidence of child cough and rapid breathing, and showed that a per kilogramme increase of INR 2.5 in the over-the-counter refill price reduced LPG usage by low-income households by about 10%. This, in turn, led to an increase in neonatal mortality of about 12.5 infants per 1000 births.

When we interacted the amount of monthly cash in hand with the PMUY status, we found a positive coefficient, which implies that the effect of variations in the over-the-counter price was tempered when

households had more cash in hand. We conjectured that the sensitivity to variation in the over-the-counter refill price was explained by the liquidity constraints of the household.

Of course, there may be other explanations as well. For example, the sensitivity could just be an income effect stemming from general inflation. However, we found no impact of the general consumer price index on refill demand. Similarly, our results were not explained by households' understanding of the subsidy and how it functioned, their access to financial services, or their trust in the government.

We concluded that a fiscally neutral redesign of the LPG subsidy programme from a cashback system to a subsidy at the point of purchase could have tremendous impacts in terms of increasing the take-up of this clean fuel by poor households that are often liquidity constrained. When designing clean energy subsidy programmes, it is important to take into account the fact that fluctuations in the market price of clean fuels adversely affect poor households' take-up as a result of the liquidity constraints they face in these low-income (mostly agricultural) settings.

3. RAISING AWARENESS: HEALTH AND SUBSIDY INFORMATION CAMPAIGN

Could it be possible that households in low income settings, with accompanying low levels of education, are unaware of the adverse health effects of indoor air pollution? If so, can increasing awareness of the adverse health effects of cooking with dirty fuels induce households to shift to cleaner sources of energy?

In the next study I discuss, we designed a randomized control trial of a health campaign to increase awareness of the adverse effects of inhaling indoor smoke in central India (the same geographical area as in the above study). At baseline (before intervention), 88% of the randomly sampled households were either unaware of the adverse health effects or thought that smoke inhalation causes only short-term discomfort. We found that 97% of the households were unable to correctly answer whether specific ailments (e.g. cardiovascular diseases and pre-term births) can be caused by indoor air pollution (Afridi *et al.*, 2023).

We found that 75% of these households had used firewood in the past month for cooking, and that 74% of the households had also used LPG for cooking in the past month. Therefore, there was significant mixed fuel usage in this context. In addition, we tested households' understanding of the cashback LPG subsidy programme. We found that more than 50% of the households did not correctly comprehend the programme eligibility and the cashback transfers.

We followed up with a low-cost intervention that aimed to increase the take-up of clean fuels by increasing health awareness in one treatment group. In another treatment group we aimed to increase both health and subsidy awareness. We leveraged the existing rural public health infrastructure to run the information campaign at a cost of about 5 USD per household. Accredited rural health workers made six visits to the treated households over a nine-month period to show informational videos on the health effects of indoor smoke and testimonials from doctors. For the health and subsidy information group, besides health information, the health workers discussed the LPG subsidy. In the control group of households, no information was provided.

Our main outcome of interest was the number of LPG refills purchased before and after the intervention (relative to the control group) using the administrative data on LPG refill consumption. We found no impact of the campaign on LPG refill consumption at an annual frequency in either treatment group. However, we did observe positive effects at the monthly frequency when we accounted for regional and seasonal variations in refill demand. There was a 13% increase in the monthly LPG refill consumption, along with a 50% increase in the use of electric stoves in the health and subsidy information group.

In this setting, using electricity may be cheaper than buying LPG cylinders, because most of these households were not paying for their electricity usage. Either households did not pay because their electricity usage fell below a threshold level, or the households used electricity illegally and therefore did not get billed. Thus, the recurring cost of using electricity was often lower than the cost of purchasing LPG refills, making it cheaper for households to switch to induction cooking.

In the health information only group, we did not observe any increase in the consumption of LPG refills, but we did find evidence of mitigating behaviour. The probability that the household had a separate kitchen increased by five percentage points. There was a shift towards using less solid fuel, although the households were not able to transition completely to LPG. They were more likely either to have an outlet for smoke or to use a separate room as a kitchen after the intervention. Thus, these households made adjustments, within their financial constraints, to mitigate the adverse health effects of indoor smoke.

These findings show that, although informational interventions may bring about behavioural changes, their impact may not be large enough for transformational shifts to clean energy usage as long as financial constraints continue.

4. WOMEN'S USE OF TIME: IMPROVING THE VALUE OF WOMEN'S TIME

I now come to the third fact related to women's roles in making the transition to clean fuels (Afridi *et al.*, 2023).

Women, particularly in the rural context, spend a large amount of their time cooking, as shown by time use survey data from the same rural context in India shown in Figure 4. Can using LPG for cooking enhance the home productivity of women and save time? We asked the women, who were the primary cooks, "How much time does it take you to prepare a meal for your family?" We compared the time use of these women in households which do not have LPG access against the time use of those with LPG access. We found that it took about 30 minutes less to prepare a meal if the woman used LPG rather than a solid fuel for cooking (Figure 5).

Consequently, when we matched households with similar characteristics, but with and without LPG access, we observed less time spent on fuel collection and fuel making by these women (Figure 6). There was potentially a large reduction in the time spent in dung collection (70 minutes or so). It is worth noting, however, that fuel collection is an activity undertaken once a week or about four times a month. Further, 30 minutes is not a sufficient time saving for

the women to step out of their homes and take up full-time jobs. Not surprisingly, our analysis suggest that the time saved was reallocated to leisure. Thus, the women in LPG access households had more time for leisure.

We leveraged the awareness and information campaign I discussed previously to estimate the effects of the campaign on the time use of these women. Not surprisingly, we found only about five minutes per day of time saved, despite the fact that there was a 13% increase in the monthly usage of LPG because of the campaign.

How do we value this time that women are saving, whether we look at the potential time, which is about 30 minutes or so, or the fact that the actual time saved as a result of the intervention was very low? In these rural areas the work available is primarily manual and low-skilled, with low wages. The potential time saving of about 30 minutes, estimated at the baseline, is valued at only about 5% of the rural monthly household income, given the rural daily wage for the unskilled, manual labour that corresponds to these women's education and skills. Hence these households do not have a large enough incentive to save the women's time spent in cooking and fuel collection by shifting to LPG. The five minutes per day of saving due to the campaign translates into about 35 minutes per week, and constitutes just about 1% of a rural household's income. Furthermore, if the technology is such that women are not able to save large chunks of time in one go, which would allow them to work full-time and bring in a substantive income to the household, the incentive for the adoption of clean fuel is even lower.

Not only is the value of women's time relatively low but there are very few opportunities for flexible work for women in this context. The average female employment rate in the context is only 15% and working women are primarily self-employed in agriculture. Access to manufacturing jobs or service sector jobs, which give higher returns and increase the opportunity cost of domestic work, is almost absent. These disincentives for adopting clean technology are heightened by the fact that it is typically men who make decisions about the purchase of LPG refills. Thus, the low bargaining power of these women further binds them into the use of dirty fuels.

5. CONCLUSION

To summarize, the discussion highlights the following:

First, providing clean fuel subsidies is not sufficient for a transformative clean energy transition. The timing of these transfers, and not just their amount, can be extremely important in the take-up of the subsidy in the context of liquidity-constrained households.

Second, while behavioural changes may lead to the greater adoption and usage of clean fuels, there may not be substantive increases in usage because of the financial constraints faced by poor households.

Third, structural constraints can impede large shifts to clean fuels in poor economies. The demand-side constraints to women's labour force participation and the low returns on their labour can disincentivize poor households from shifting to more efficient and cleaner fuels.

These findings suggest new areas for further research on clean energy transition. First, how do we design an optimal clean energy subsidy programme – in terms of both the amount of the subsidy and its delivery? India's LPG subsidy programme has been cut back from a 50% universal subsidy to a 30% targeted subsidy today, with no change in its cashback nature. Interestingly, under the Inflation Reduction Act passed by the Biden administration, the US government shifted from a cashback system to an upfront subsidy of USD 7,000 for electric vehicles, to incentivise the shift towards electric vehicles.

In labour and environmental economics, we need more research to better understand how indoor air pollution impacts labour productivity, particularly by gender. What is the role of structural transformations of the economy in clean energy technology adoption? How do intra-household dynamics impact clean energy adoption?

There is much more research needed for us to understand and hasten the transition to clean energy by the world's poor and marginalized.

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ANNEX

Figure 1: *The energy ladder*

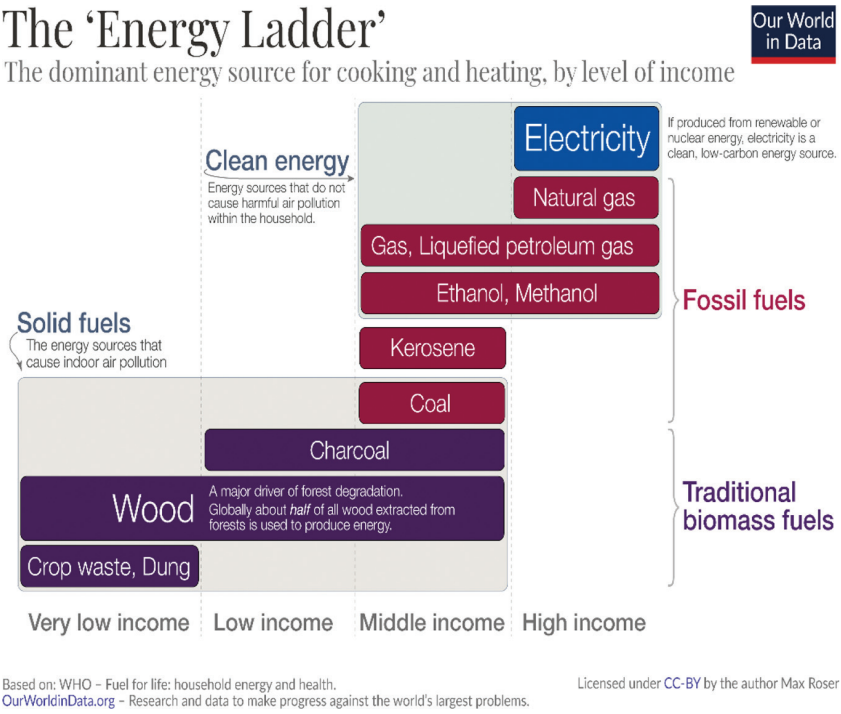
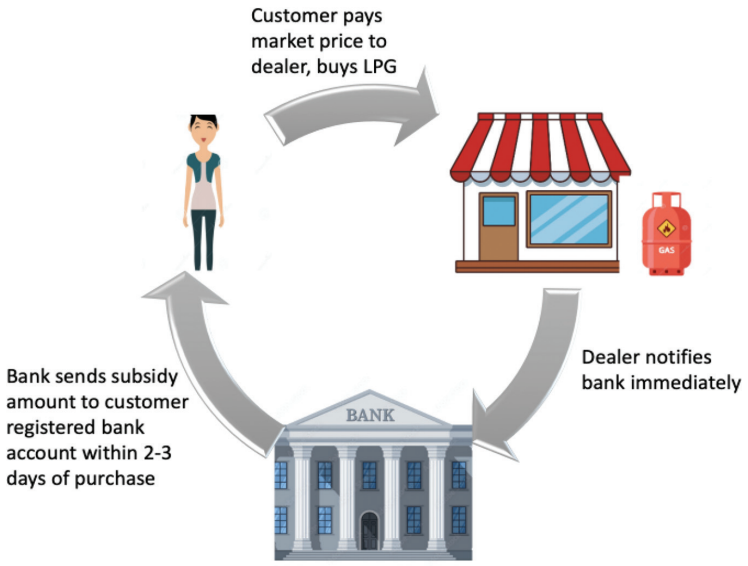
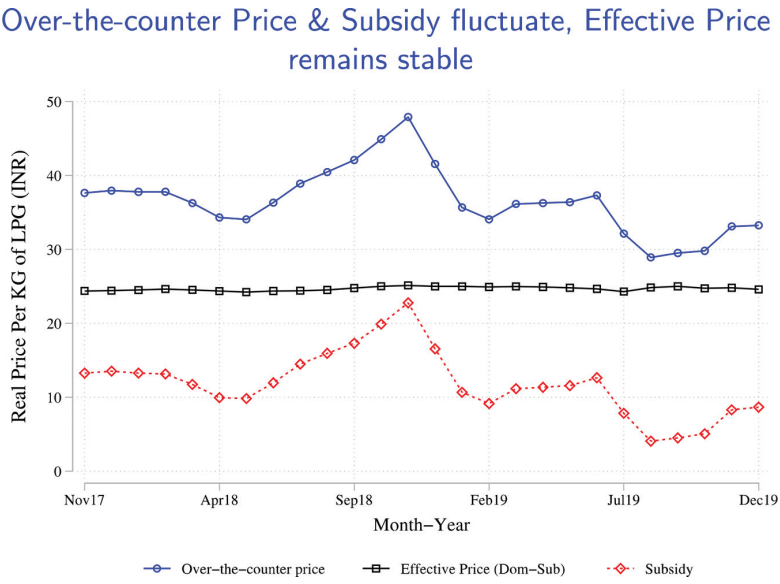


Figure 2: *India's LPG refill subsidy programme*



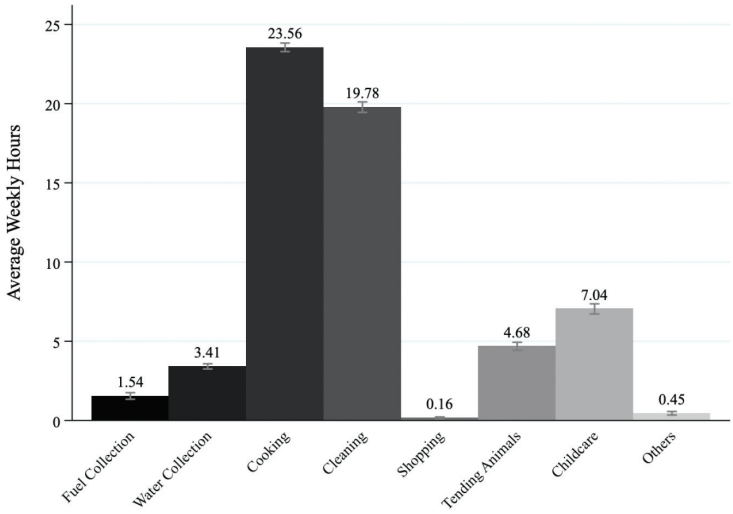
Source: Afridi, Barnwal and Sarkar (2024).

Figure 3: *LPG price and subsidy*



Source: Afridi, Barnwal and Sarkar (2024).

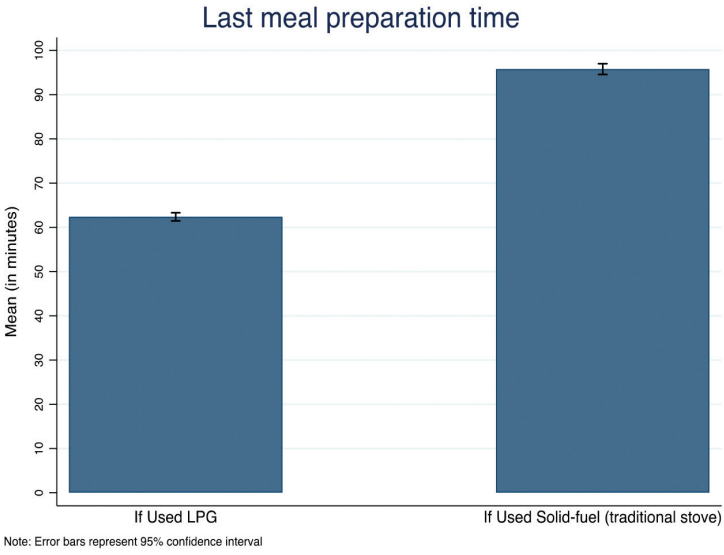
Figure 4: *Women's time use*



Source: Afridi *et al.* (2023).

Note: Total time spent on domestic work per week is 60.62 hours; N=2942.

Figure 5: *Time taken to prepare last meal, by type of cooking fuel*



Source: Afridi *et al.* (2023).

Figure 6: *PSM estimates of switching to LPG*

Minutes	**Average Treatment Effect on Treated (LPG vs. non LPG household) [N=2650]**
Time spent on firewood collection (per week)	–7.26
Time spent on dung collection/making (per week)	–69.91***
Time spent on domestic work (per day)	–19.86**
Fuel Collection	–4.66**
Cooking	–6.23*
Time spent on income-generating work (per day)	–5.58
Time spent on leisure (per day)	20.72***

Source: Afridi *et al.* (2023).
Note: Price Sensitivity Meter helps determine the psychologically acceptable range of prices for a single product or service. Significant at *10%, **5% and ***1%.