The Effect of an Increase in Economic Well-being on the Fuel Consumption Choices of the Poor in India

Online Appendix

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1 Appendix 1: Conceptual Framework

To motivate our empirical exercise, we explore the relationship between capital and fuel consumption within the context of simple unitary household model. Assume that household utility, $U(x, q_d)$, depends on two groups of goods: consumption, x (which may include clean fuel) and dirty fuel, q_d.[1] Fuel is used for multiple activities, e.g. cooking and lighting. Households face diminishing marginal utility in both consumption and the dirty fuel, such that $U_x > 0$, $U_{q_d} \geq 0$, $U_{xx} < 0$, and $U_{q_d q_d} < 0$. Note that q_d and x can be either complements or substitutes, so $U_{q_d x} \gtreqless 0$.[2] We also assume that $U_{q_d x} \geq \max(U_{q_d q_d}, U_{xx})$, i.e. that the change in marginal utility for dirty fuel induced by an increase in consumption cannot be lower than the change in marginal utility in consumption induced by an increase in consumption or the change in marginal utility of fuel induced by an increase in fuel; in other words, households like a mix of products.

Household income includes non-labor income, I, as well as income from household production, $f(k, l)$, which depends on capital (k) and labor devoted to household production (l).[3]

[1] The basic intuitions from the three goods case (a dirty fuel, a clean fuel and other consumption) are similar to the two-good case. Thus, while we present the two-good case for simplicity, we can also provide three-good case upon request.

[2] In the extreme case of perfect substitution between x and q_d, we have $U_{q_d x} = U_{q_d q_d} = U_{xx}$.

[3] In the rural areas of developing countries, many households typically engage in home production.

We assume that capital and labor are complements, such that $f_k > 0$, $f_l > 0$ and $f_{lk} > 0$. Households face a time constraint given by $\bar{L}$. Hours devoted to household production, l, are given by $\bar{L} - h(q_d)$, where $h(q_d)$ are hours lost to sickness. We assume that dirty fuel increases hours of sickness, $h_{q_d} > 0$; and that the marginal harm of fuel increases with the use of fuel, $h_{q_d q_d} > 0$.[4]

We assume that households are aware of the health damage associated with the consumption of dirty fuel.[5] Hence, households maximize utility, $U(x, q_d)$, subject to $I + f(k, \bar{L} - h(q_d)) = p_d q_d + x$. The lagrangian for this optimization problem is given by:

$$L(x, q_d, \lambda) = U(x, q_d) - \lambda \left(p_d q_d + x - I - f(k, \bar{L} - h(q_d))\right)$$

with first order conditions given by:

$$L_{q_d} = U_{q_d} - \lambda \left(p_d + f_l(k, \bar{L} - h(q_d))h_{q_d}\right) = 0 \tag{1}$$

$$L_x = U_x - \lambda = 0 \tag{2}$$

$$L_\lambda = p_d q_d + x - I - f(k, \bar{L} - h(q_d) = 0 \tag{3}$$

First differentiating the first order conditions with respect to k, and solving for $\frac{dq_d}{dk}$ yields the following expression for the response of dirty fuel consumption to an exogenous increase in productive capital:

$$\frac{dq_d}{dk} = \frac{-f_k U_{xx} p_d' + f_k U_{q_d x} - U_x f_{lk} h_{q_d}}{\Delta} \tag{4}$$

[4]The available evidence suggests that pollution reduces work hours (Hanna and Oliva, 2013) and also has productivity impacts (Graff Zivin and Neidell, 2012). While we do not have any strong evidence on whether the relationship between pollution and hours of work is non-linear, Jayachandran (2009) and Areco, Hanna and Oliva (2012) suggest that the relationship the marginal effect of pollution on health may be increasing in pollution levels.

[5]Jeuland, Pattanayak, and Tan Soo (2013) show that 62 percent of households from a sample in rural India were aware of the negative health effects of cooking fuel, and so this assumption may be reasonable. However, it is possible that individuals do not fully comprehend the health effect when making fuel purchasing decisions, even if it does adversely affect their labor supply. In this case, the household's decision to purchase dirty fuel will depend only upon wealth and substitution effects, i.e. the health production effect that we document would not enter into their decision. Under this scenario, the overall effect of the capital shock on the purchase of dirty fuels would only be negative if it is an inferior good.

where $\Delta = \left((-U_{q_d q_d} + U_{q_d x} p'_d) + (U_{q_d x} - U_{xx} p'_d)\, p'_d + U_x \left(-f_{ll} h_{q_d}^2 + f_l h_{q_d q_d} \right) \right)$ and $p'_d = p_d + f_l h_{q_d}$. Note that p'_d represents the effective price of dirty fuel: the sum of the market price and its cost in terms of the productivity loss. The assumption that $U_{q_d x} \geq \max(U_{q_d q_d}, U_{xx})$ implies that $\Delta > 0$, hence the sign of (4) is fully determined by the sign of the numerator.[6]

The first term in (4), which can be interpreted as the wealth effect on dirty fuel, is unambiguously positive. It is proportional to the second derivative of the utility function with respect to consumption: as the marginal utility of consumption decreases with the increase in wealth, represented by f_k, individuals buy more of the dirty fuel.

The second term in (4) can be seen as the substitution effect. It can be positive or negative depending on the substitutablity or complementarity between the dirty fuel and consumption (which also include clean fuels). If they are compliments (e.g. consumption includes more food that needs to be cooked or books that one bought to be read at night), then this term will induce a larger purchase than just from the wealth effect. If they are substitutes (e.g. cleaner fuels that can be used instead of dirty ones), this will reduce purchases. However, note that for the substitution effect to dominate the wealth effect, dirty fuel would have to be an inferior good.

Unlike the standard microeconomic models, there is an additional third term that determines the purchasing decisions: this represents the health production function effect and is negative. Intuitively, as capital increases, labor becomes more productive and individuals are discouraged from purchasing health-damaging fuel. If this effect dominates, the overall effect of an asset shock on dirty fuel use will be negative.

In conclusion, the effect of a capital shock on dirty fuel use is ambiguous, with the sign of the effect depending on how easily can it be replaced by other consumption goods, including

[6]To see that $\Delta > 0$, note that if $U_{q_d x} = U_{xx} = U_{q_d q_d}$, then:

$$(-U_{q_d q_d} + U_{q_d x} p'_d) + (U_{q_d x} - U_{xx} p'_d)\, p'_d =$$
$$(-U_{xx} + U_{xx} p'_d) + (U_{xx} - U_{xx} p'_d)\, p'_d =$$
$$-U_{xx}(1 - 2p'_d + p_d^2) > 0$$

Therefore, $(-U_{q_d q_d} + U_{q_d x} p'_d) + (U_{q_d x} - U_{xx} p'_d)\, p'_d > 0$ for $U_{q_d x} \geq \max(U_{q_d q_d}, U_{xx})$.

clean fuel, and on how large the wealth and substitution effects are relative to the health production effect. Therefore, understanding how rising wealth, or how large-scale transfer programs, affect fuel use is ultimately an empirical question.

Intra-Household Bargaining

In our simple set-up, we assumed that households act as a single economic unit. However, different household members may have more of a say in the household decisions given their bargaining power. If all members of the household have the same preferences, this would not affect our model. But, one can imagine that different members may have different preferences for fuel types (e.g. one person may like the smokey flavor that comes from cooking with a dirty fuel, while another may dislike that same taste). Similar, different households members may be differentially exposed to the dirty fuel (e.g. maybe all households members are exposed to smoke from a kerosene lamp, but women are primarily exposed to smoke from dirty cooking fuels) or face differential costs from doing so (e.g. the productivity effect differs based on one's propensity to fall ill from smoke). Under a model of intra-household bargaining, the purchasing decision would still be determined by the relative magnitudes of the wealth, substitution and health effects, but how these enter final decision depends on the preferences and relative bargaining power of each household member.

Simultaneous Drop in the Price of Dirty Fuels

It is not uncommon to observe complementarities in the different household production processes that lead to simultaneous effects across several production processes. In our particular context, capital is often in the form of livestock: cows may produce several household and commercial goods including dairy products, agricultural services (plowing), and dung, which can be used as fertilizer or as fuel. In this case, a new cow may increase wealth and the productivity of labor, but also substantially reduce the price of cow dung. Even though cow dung is a dirty fuel, the simultaneous reduction in dung price that comes with livestock may offset the impact of increased wealth and labor productivity. Therefore, we may see households switching away from other dirty fuels (such as wood) and towards dung–or even from some clean fuels towards dung–if the price effect is substantial.

2 Appendix Table 2: Detailed Empirical Set-Up

2.1 Experimental Design

This paper exploits data from a randomized experiment that is described in Banerjee, Duflo, Chattopadhyay, and Shapiro (2010); we summarize the intervention and their data collection efforts here. The intervention was designed to improve the livelihoods of the poor in Murshidabad, West Bengal, India (a district north of Kolkata), by providing them with a productive asset, along with a small cash stipend, with the idea of eventually transitioning households to micro-finance loans.[7]

Between late 2006-Mar 2008, Bandhan, a local NGO, targeted poor households in Murshidabad district through three steps: (1) geographic targeting of poor hamlets (2) a participatory rural appraisal that consisted of a social and wealth ranking and (3) a final assessment by the project coordinator based on both quantitative and qualitative information. The program was geared towards woman, and therefore, all households that were recruited were required to have an able-bodied woman.

Half of the recruited households were randomly assigned to receive the program (which was phased in starting May 2007). Households received a grant in the form of an asset, where they could choose between 2 cows (29 percent of treatment households selected this option), 4 goats (52 percent), 1 cow and 2 goats (5 percent), or a non-farm enterprise (12 percent).[8] In addition, they received a stipend of Rs 90 (USD 2.25) for 13 to 40 weeks depending on their asset choice. Two requirements accompanied the program: first, households were required to

[7] The micro-finance loans only became available to households after the first endline survey. The results on fuel outcomes are the same in the first and second endline, suggesting that the access to finance (by itself) was not driving the results.

[8] An additional 2 percent chose a sheep or a pig.

attend livelihood meetings each week to collect the stipend; the trainings related to the asset, as well as broader social issues. The livelihood meetings consisted of different topics such as fruit tree plantation, HIV/AIDs training, child trafficking, etc. There was no mention of fuel choices for cooking or electricity and there was no discussion of the relationship between fuel and health.[9] In addition, they were required to save Rs 10 (USD 0.25) each week at these meetings. After 18 months, they were given a 3-day micro-credit orientation and thus became eligible for micro-finance loans after the first endline (the first cycle started May-Nov 2009).

2.2 Data

This project exploits data from three survey rounds. A baseline survey was collected in February 2007 to March 2008, after the targeting, but prior to the intervention. The first endline survey (Endline 1) was conducted 18 months after the asset transfer was complete and before the micro-finance orientation (Mar 2009 – Sept 2009) , while the second (Endline 2) was conducted in Jul 2010 – Feb 2011. All three surveys contained both a household module and an adult module administered to those over 18 years of age. The data include 388 control and 429 treatment households, for a total of 812 households.

All three survey rounds included consumption and asset data. We focus on fuel consumption during the last 30 days.[10] Both endline surveys additionally include a detailed fuel expenditure module, which allows us to explore the value of consumption by fuel type and by home production versus purchases. To obtain a measure of household assets, we follow Banerjee, Duflo, Chattopadhyay, and Shapiro (2010) and compute an aggregate asset holding by conducting a principal component analysis of productive assets, durable household items

[9]In many transfer and micro-finance programs, there is typically a socal component in which the cash is disbursed. Unlike other cash transfer programs that require certain behaviors (e.g. vaccination of children, school attendance), this program was unconditional on health behavior, making it very appealing to study.

[10]We also compute the ratio of fuel consumption to total non-fuel expenditures. Following convention, we code non-fuel expenditures over the last 30 days as the sum of the non-durable expenditures in the last 30 days and 1/12 of the durable expenditures over the last 12 months. The fuel consumption does not distinguish between consumption for fuel and light. Subsequent analysis from the endline surveys reveal that while it should include all fuel expenditures, electric bills tend to be systematically excluded.

and livestock.[11]

In addition, we exploit data on the household's primary cooking fuel and light source, as well as time spent collecting wood. We aggregated the data on primary cooking fuels into six main categories: dung, wood, charcoal, coke/coal, kerosene and LPG/electricity. Wood includes non-forest timber products, and LPG/electricity contains gobar, which is a form of biogas. These stove variables were only included in the baseline and Endline 1.[12] Data on primary lighting source in the household and each individual's time spent collecting wood in the past 24 hours were available in all three surveys.

Finally, we have all administrative data on the household's treatment status, as well as who took up the program. As Banerjee, Duflo, Chattopadhyay, and Shapiro (2010) discuss, the randomization was successful and attrition was not differential by treatment status. As an additional check on our variables of interest, we check the randomization for the fuel variables. None of the variables are significant at conventional levels.

[11] The asset list includes television, radio / transistor / stereo, electric fan, refrigerator, telephone / mobile phone, bicycle, rickshaw / van, sewing machine, chair/stool, cot, table, watch / clock, pairs of shoes / sandals, and structures for grain storage.

[12] In the baseline, households were allowed to choose multiple fuel types as their primary stove. In Endline 1, households were told to pick their primary fuel type for cooking, and only choose two if they used them in equal amounts; most households chose one stove type (the average number of fuel types per household is 1.01).