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The need for policies to reduce the costs of cleaner cooking in low income settings: Implications from systematic analysis of costs and benefits

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ABSTRACT

Inefficient household cooking in less-developed countries harms health and productivity, the environment, and the global climate. Interventions to encourage adoption of cleaner and more fuel-efficient stoves are being implemented widely to reduce these burdens, but sustained use has proven elusive. This study develops a data-driven simulation approach to investigate the potential costs and benefits of cleaner stoves, informed by recent empirical studies. The results suggest that the private case for adoption of technologies other than charcoal ICS is often unclear; that is, households' private benefits do not usually outweigh the costs of these improvements. Overall social benefits, in contrast, are typically positive and large for nearly all such improved technologies. We investigate how economic benefits vary with intensity of use, and find that higher use does not unambiguously translate into greater private benefits. Analyzing the effects of different subsidies, we further find that fuel subsidies for purchased fuels could substantially improve private net benefits, but that even these may be insufficient to make cleaner cooking attractive to many households; stove subsidies meanwhile tend to modestly improve private outcomes. To capture the social benefits of cleaner cooking, new and effective incentives may be needed to support household use of efficient stoves.

1. Introduction

About three billion people rely on a toxic combination of solid fuels and inefficient stoves to meet their daily household cooking and heating needs. These households inevitably incur significant health and productivity costs, and impose serious environmental damages at regional and global scales (Anenberg et al., 2013; Lim et al., 2013; Smith et al., 2013). In particular, pollution emitted from inefficient stoves burning solid fuels is responsible more than 4 million deaths each year and accounts for about 25% of global emissions of black carbon (BC) – an extremely potent climate forcer in the short term (Lim et al., 2013; Martin et al., 2014; Myhre et al., 2013). Meanwhile, unsustainable solid fuel harvesting damages forest ecosystems (Bailis et al., 2015). In light of these negative effects, increasing attention and resources are being directed towards interventions that develop and distribute cleaner improved cookstoves (ICS) to poor households.[1] Yet important questions remain about who should pay for the improved technologies and whether it makes sense for households to adopt and use potentially more expensive stoves and fuels (Jeuland et al., 2015).

The literature on the economics of ICS often argues that the private net benefits (health, productivity, and fuel savings) provided by such technologies are large even without including environmental benefits, and that household should therefore adopt them. For example, one recent study that included only private benefits (health, time and fuel savings) estimated that the annual global net benefits of switching from traditional to various improved cookstoves (ICS) reaches between US $18 and US$54 billion (Larsen, 2014). Earlier cost-benefit analyses projected similarly large net benefits, also noting that ICS adoption was cost-saving for households (Hutton et al., 2007).

Importantly, such calculations are hard to reconcile with the reality of highly varied demand, use, and impacts of ICS technologies following promotion in many settings. Numerous examples exist – in both the distant and recent past – of dissemination programs and demand studies that have demonstrated low demand over the short and medium term

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[1] We use the term improved cookstove (ICS) to refer to a large range of technologies, specifically those that appear in the Global Alliance for Clean Cooking (GACC) clean cooking catalogue plus other published studies that claim to consider improved options. We acknowledge that the term ICS has become controversial, but explain the reasons for applying this inclusive definition in Section 2.

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(Barnes et al., 1994; Bensch et al., 2015; Cundale et al., 2017; Gall et al., 2013; Hanna et al., 2016; Mobarak et al., 2012; Ruiz-Mercado et al., 2011). While innovative promotion experiments developed to address classical problems of technology adoption (e.g., informational and liquidity constraints, present bias, lack of female bargaining power) have demonstrated higher demand (Beltramo et al., 2015; Levine et al., 2018; Pattanayak et al., 2018), as well as impacts on livelihoods (Bensch and Peters, 2013, 2015; Beyene et al., 2015; Pattanayak et al., 2018), these more favorable results remain somewhat limited. At first glance, the results of the bulk of the studies' that contradict the global cost-benefit calculations are puzzling, and firstly suggest that households in many low-income settings are not making forward-looking decisions. An alternative supposition, which we explore in this paper, is that these prior net benefits calculations are perhaps somewhat misleading. For example, they may rely on inconsistent or incomplete valuation measures, may be based on studies conducted in locations or with technologies for which net benefits are most likely to be positive, or may make optimistic assumptions about the ways people use and benefit from technology, for example ignoring learning or adaptation costs (Bensch and Peters, 2015; Gebreegziabher et al., 2018). In addition to these shortcomings, it is worth noting that analyses pointing to high net benefits are largely deterministic and underappreciate real world variability in costs and benefits (Whittington et al., 2012).

This study attempts to address these shortcomings by applying evidence from the burgeoning empirical literatures on the exposure-health, climate, and social sciences aspects of this problem. We use this evidence to derive new estimates of the net benefits of switching from a traditional stove to various ICS, to compare the consistency of deterministic and probabilistic results, and to derive insights on the role of fuel and stoves subsidies in promoting adoption and usage of various types of ICS. The basic approach is implemented as follows, building from a methodology described by Jeuland and Pattanayak (2012). We start from a typology of the costs and benefits of adoption of ICS, distinguished by stove-type and fuel. The included benefits are health – morbidity and mortality reduction, and health spillovers from better ambient air quality; productivity, or time savings; and environmental – reduced climate forcing and deforestation. Costs include technological and program costs; operation, maintenance, and fuel costs; and learning. Next, these various costs and benefits are represented by valuation equations specified on the basis of the latest scientific and economic research. Third, we comb the literature in relevant fields to specify plausible real-world variation in each of the roughly thirty parameters appearing in these equations.[2] Finally, we run 10,000 Monte Carlo simulation trials to generate ranges and distributions of net benefits for each ICS. Because the parameters have been sourced from the literature, we believe that the outcome distributions reflect the variation that is likely to exist in developing countries; importantly we can further study this variation to obtain insight on which parameters are most influential in affecting the simulated outcomes. Still, we emphasize that the frequency with which any specific combination of parameter values – or net benefit outcomes – would arise is unknown. This may be important due to the site- or intervention-selection bias (Allcott, 2015) that may exist in field research or reports on ICS issues.[3] Thus, our outcome distributions should not be interpreted to represent the precise distribution of real-world outcomes. Indeed, the major shortcoming of our approach is that the simulations may create combinations of stove characteristics that one does not often find in the real world, though the direction of any bias that might result from this issue is unclear.

All categories of costs and benefits are expressed in present value terms, with future costs and benefits discounted using an exponential discount function. This logic applies for the climate benefits as well. Hence, we derive a time-varying radiative forcing for each climate-altering pollutant produced by different cookstoves to compute a present-value discounted global warming impact for each technology (Shindell, 2015).

To build intuition on the importance of various categories of costs and benefits, we first compare results when all parameters take on the average model values, before presenting the Monte Carlo simulation results. We show: 1) The private net benefits of ICS adoption (Private); 2) A narrow definition for social net benefits (Social), which includes private benefits plus health spillovers and averted deforestation and relevant Kyoto protocol pollutants (carbon dioxide, methane and nitrous oxide); and 3) A more complete definition for social net benefits (Social+), which adds changes in emissions of other important climate-altering pollutants (BC, carbon monoxide (CO), non-methane hydrocarbons (NMH), and organic carbon (OC)) (IPCC, 2013). BC in particular is a powerful positive forcer produced in abundance by residential biomass fuel burning (Bond et al., 2013). We briefly discuss sensitivity analyses that provide insights on which parameters drive variation in the simulation results.

Finally, we analyze how the distributions of private net benefits for the socially most beneficial technologies shift as a function of: 1) use of the improved option; 2) subsidy for purchase of a cleaner stove; and 3) subsidy for purchase of the fuel required by that stove. The purpose of the former analysis is to explore the importance of the intensive margin of adoption for altering net benefits, given that households can clearly optimize behavior on this margin. The latter two analyses then shed light on the extent to which two specific price instruments are helpful in making private use of cleaner technologies attractive to utility-maximizing households. We can also compare the likely relative effects – on private net benefits – of fuel vs. stove subsidies. While it is obviously true that subsidies will increase the private net present value (NPV) of a switch to cleaner ICS technologies, we show that it is very much an empirical question whether such measures are sufficient to make them attractive (i.e., private NPV > 0), given real world heterogeneity in cooking conditions and constraints.

2. Methods and data

Our model compares the costs and benefits of households' switching from traditional stoves to various alternatives – thus, the NPV we calculate assumes that a household adopts the new technology. In other words, we abstract away from the extensive margin of adoption. This is useful in illuminating whether a decision to adopt can be considered rational, from the household and social perspective. Most modeled transitions are from a traditional firewood stove, except for charcoal,

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[2] These parameters include aspects related to stove and fuel prices and other characteristics (longevity of stoves, time and thermal efficiencies, fuel calorific content); maintenance and promotion program costs; behavioral parameters (cooking time, fuel needs and collection time, stove use rates); baseline health conditions (incidence or prevalence of, and mortality from, diseases related to household air pollution); emission rates and the climate and health effects of emissions; and valuation parameters for time savings, health and environmental consequences.

[3] Several dimensions of potential selection bias deserve mention here, although we admit that we are not aware of work documenting their existence in this context. The technologies studied by researchers, or discussed in grey literature produced by NGOs, donors, or international organizations such as the Global Alliance for Clean Cookstoves (GACC), may be systematically different from those deployed in the real world. In addition, our primary source for stove characteristics – which is supplemented by information in specific research studies – is the GACC stove catalogue, which may itself contain technologies that are systematically different from those studied by researchers (in terms of aspects such as efficiency, beneficiary usage, etc.). In particular, it seems possible that stoves studied in the field are more efficient than the options that are generally available to households, because most ICS research has been focused on health. It is also possible that study sites may be selected to produce positive outcomes (since researchers usually prefer to avoid null or negative results), though bias in the opposite direction also seems possible (for example if researchers focus on remote or other low demand contexts, or on unproven technologies). We are unaware of evidence suggesting a systematic bias towards more or less favorable sites, but this issue is worthy of additional investigation.