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Analysis

Improving stove evaluation using survey data: Who received which intervention matters

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ABSTRACT

As biomass fuel use in developing countries causes substantial harm to health and the environment, efficient stoves are candidates for subsidies to reduce emissions. In evaluating improved stoves' relative benefits, little attention has been given to who received which stove intervention due to choices that are made by agencies and households. Using Chinese household data, we find that the owners of more efficient stoves (i.e., clean-fuel and improved-biomass stoves, as compared with traditional-biomass and coal stoves) live in less healthy counties and differ, across and within counties, in terms of household characteristics such as various assets. On net, that caused efficient stoves to look worse for health than they actually are. We control for counties and household characteristics in testing stove impacts. Unlike tests that lack controls, our preferred tests with controls suggest health benefits from clean-fuel versus traditional-biomass stoves. Also, they eliminate surprising estimates of health benefits from coal, found without using controls. Our results show the value, for learning, of tracking who gets which intervention.

1. Introduction

Approximately 3 billion people in developing countries face health risks associated with the use of biomass for energy such as the burning of wood, dung and crop residues (IEA, 2010).[2] Exposures largely are indoors, given higher indoor concentrations and all the time spent indoors (Smith et al., 2004). Biomass fuels often are used in poorly ventilated places, with open fires or inefficient stoves, yielding pollutant levels well above the average exposures within a dirty city (Smith, 1993). These exposures often vary greatly by household member (Smith et al., 2004), as men spend more time outdoors while children spend time indoors with women, who are cooking.

The World Health Organization found that indoor smoke accounts for almost 4% of the burden of disease in developing countries, ranking indoor air pollution 4th among all the sources of disease burden — following malnutrition, unprotected sexual relations, and poor water quality and sanitation (Ezzati et al., 2004). That magnitude motivates, at the least, quality evaluation of interventions.

Those facts have led to studies of health risks and biomass fuel use. Published evidence suggests that changes in what biomass is used, and how, can reduce related risks to health (Boy et al., 2002; Bruce et al., 1998, 2004; IARC, 2010; McCracken et al., 2007; Mishra et al., 2004).[3] Major reviews have concluded that household air pollution from solid cookfuels is associated with risks of chronic obstructive pulmonary disease (COPD), lung cancer, cardiovascular disease, cataracts, and child acute lower respiratory infections (ALRI) (Lim et al., 2012). Evidence is growing of other important outcomes including tuberculosis, cervical cancer, adverse pregnancy outcomes, asthma, and cognitive effects in children (Baumgartner et al., 2011; Dix-Cooper et al., 2012; Lin et al., 2007; Pokhrel et al., 2010; Pope et al., 2010; Velema et al., 2002; Wong et al., 2013). Such findings have inspired projects worldwide, e.g. the Global Alliance for Clean Cookstoves, to disseminate and to commercialize emissions-reducing stoves.

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[2] We focus on direct local health impacts but note that indoor pollution becomes outdoor and atmospheric pollution. IPCC's 4th Assessment Report says household usage of biomass and coal for energy contributes to carbon emissions.

[3] Recommended action may differ for developed countries. Moshammer et al. (2006) suggest room ventilation, e.g., following analysis of the impact on children's lung function of cooking with natural gas (a 'clean' fuel in our work).

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Many findings on impacts of stove interventions are however subject to selection biases given various choices by agencies and households (Heckman and Smith, 1995) — which can lead the stove that a person uses to be correlated with her health for reasons other than stove impacts. Such correlations can confound the accurate estimation of an improved stove's impact on health. For example, clean stoves might be adopted more by those with poor housing ventilation, as their benefits from lowering stove emissions may be higher given longer exposure to those emissions. If that is so and in addition poor ventilation is associated with a low score on the health measures used in an evaluation,[4] it is easy for that evaluation to underestimate the clean stove's benefit.[5]

To illustrate how such confounding correlations might come about, due to local choices, we provide background about stoves in China.[6] We then describe our household data from China and analyze it using regression and matching techniques[7] (Abadie and Imbens, 2002; Rosenbaum and Rubin, 1983) to address confounding influences. We see that biased impact estimates arise from non-random distributions of improved stoves. Different stoves (coal, traditional-biomass, improved-biomass, and the 'clean-fuel' which use electricity, liquefied petroleum gas, or biogas) are owned by households who differ in health-relevant characteristics, e.g., some are older or are poorer or have kitchens featuring poorer ventilation. Such differences, if correlated with stoves, create the potential for biases in stove-impact evaluations, if they are not adequately addressed.

Given our dual goal of both highlighting and, at least in part, addressing potential biases, we present our different results in two ways. We provide the impact estimates from our preferred specifications, which all include individual and household characteristics plus county indicators. For example, versus traditional-biomass stoves, we find gains from using clean-fuel but not from improved-biomass stoves. We find no benefits from clean-fuel versus improved-biomass stoves, nor gains from any other stoves relative to coal stoves. The latter is surprising, given past results.

We also show how the inclusion of counties and of household characteristics significantly shifted our estimates. Without including controls, our analyses comparing to traditional-biomass suggest no benefit from the clean-fuel and, if anything, losses from the improved-biomass stoves. The reason is that the owners of more efficient stoves (clean-fuel, improved-biomass) are poorer and live in counties where, on average, people are less healthy. Controls for such key differences suggest gains from more efficient stoves. We also find that the traditional-biomass stoves appear to be *worse* for health than coal, controlling only for the provinces, but this result vanishes if we include indicators for county, i.e., finer controls for differences in local policies and conditions. Even when controlling for county, though, the improved-biomass stoves appear *worse* for health than coal stoves. Inclusion of household characteristics eliminates that surprising result. In sum, intuitive effects are supported and counterintuitive ones eliminated by including more controls.

The rest of the paper is as follows. Section 2 describes relevant stove programs in China. Section 3 presents the large data set at our disposal, based upon a survey of Chinese households. Section 4 presents our methods and sketches why household decisions can complicate evaluation in a simple regression framework. Section 5 then provides our results, while Section 6 concludes.

2. Stove Programs & Stove Adoption

From the early 1980s, the Chinese National Improved Stove Program (NISP) facilitated the dissemination of efficient biomass and improved coal stoves (Sinton et al., 2004), in support of 860 counties (of 2126 countrywide). Some provinces and counties took separate initiatives to promote stoves. The Agriculture Ministry was responsible for direct subsidies to households, who paid for materials and installation. The fraction of their costs that was subsidized depended on the stove and the county. Counties applied for such funding and were chosen to participate based on, e.g., energy shortages and their willingness to share the cost. The partial subsidies, until 1990, led to rapid stove dissemination (Smith et al., 1993). Although primarily designed to improve fuel efficiency, NISP only disseminated chimney stoves, which also lowered indoor pollution levels (Edwards et al., 2007).

During the 1990s, though, stove distribution no longer relied on subsidies to households (rural energy companies still received tax and loan benefits, plus training and administrative support (Sinton et al., 2004). The Ministry of Health, however, had a separate program to reduce fluorosis in areas dependent on high-fluoride coal. A State Development Planning Commission supported stoves to promote reforestation and reduce floods (Sinton et al., 2004). To reduce biomass usage — a goal unrelated to health — the latter agency promoted rural coal markets to convert biomass users to use of coal.[8]

Over time, household choices became more important to the distribution of these stoves, particularly given a phasing out of subsidies after 1990. Sinton et al. (2004) state: "Unlike many improved stove programs in other countries (such as India), households bore most of the direct costs of stove purchases." (p.39); and, further: "Households paid about 94% of all costs" (p. 40). Which households received which if any of the new stoves being promoted, then, very likely was driven by factors determining related household choices, including liquidity or credit constraints, preferences, and knowledge about such stoves. Household choices clearly can be critical, while the details of what programs were promoted and where obviously also affect stove allocations.

3. Data

We use a cross-sectional survey of about 3500 households within three provinces in China (Shaanxi, Hubei, and Zhejiang) that was collected in 2001–2003 to help evaluate policy impacts. It includes information on: health outcomes for adults (age 18 and over); demographics; fuel use; and the use of stoves by type (Sinton et al., 2004). We focus on stoves used mainly for cooking. Four types are in our sample: traditional-biomass (16%), improved-biomass (47%), coal (32%), and clean-fuel (6%). Stoves are defined by the types of fuels they use. Both traditional-biomass and improved-biomass stoves

[4] Bruce et al. (1998) and Dasgupta et al. (2006), for instance, demonstrate that related dwelling characteristics are, in fact, significant determinants of the health outcomes within studies done in Guatemala and Bangladesh, respectively.

[5] A bias in the opposite direction is also possible. See the discussion within Section 2 below, and in Pitt et al. (2006), where the story is not higher marginal damages without ventilation but lower earning losses if the sick are exposed.

[6] Peabody et al. (2005) compare effects of using traditional biomass, improved biomass, or clean cooking stoves relative to coal on a suite of health outcomes. They find significant benefits of improved biomass stoves in reducing respiratory disease, COPD and exhaled carbon monoxide (CO), and in increasing forced vital capacity (FVC) or lung capacity. Improved biomass stoves also do better than traditional biomass stoves for respiratory disease, COPD, exhaled CO, and FVC. History of asthma was not found to be a significant determinant in either comparison. We use self-reported health to consider additional comparisons of stove types using the China household survey analyzed in some other work (Edwards et al., 2007; Peabody et al., 2005; Zhang and Smith, 2007).

[7] Matching has been used to estimate impacts for job training (Dehejia and Wahba, 1999; Heckman et al., 1997), health (Hill et al., 2003) and forest conservation (Andam et al., 2008; Pfaff et al., 2009; Robalino and Pfaff, 2013). Applications to stoves are scarce (Mueller et al., 2011). Some have randomized stoves (Bensch and Peters, 2012; Hanna et al., 2012; Mobarak et al., 2011; Smith et al., 2006). That addresses many of the behaviorally based potential biases (without demonstrating their magnitudes).

[8] This can affect stoves' associations with health: if wealthier households in target regions are healthier than others, if coal stoves are promoted, and if the wealthier adopt them more, then non-health policy links coal to better health.