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The intensive margin of technology adoption – Experimental evidence on improved cooking stoves in rural Senegal☆

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ABSTRACT

Today, almost 3 billion people in developing countries rely on biomass as primary cooking fuel, with profound negative implications for their well-being. Improved biomass cooking stoves are alleged to counteract these adverse effects. This paper evaluates take-up and impacts of low-cost improved stoves through a randomized controlled trial. The randomized stove is primarily designed to curb firewood consumption, but not smoke emissions. Nonetheless, we find considerable effects not only on firewood consumption, but also on smoke exposure and, consequently, smoke-related disease symptoms. The reduced smoke exposure results from behavioural changes in terms of increased outside cooking and a reduction in cooking time. We conclude that in order to assess the effectiveness of a technology-oriented intervention, it is critical to not only account for the incidence of technology adoption – the extensive margin – but also for the way the new technology is used – the intensive margin.

1. Introduction

In developing countries, almost 3 billion people rely on traditional biomass-based fuels for their daily cooking purposes. In rural sub-Saharan Africa, virtually all households cook with biomass, mostly firewood. The collection of and cooking with firewood is associated with various negative effects on the living conditions of the poor. According to the World Health Organization (WHO), the emitted smoke is the leading environmental cause of death and is responsible for 4.3 million premature deaths every year – more deaths than are caused by malaria or tuberculosis (WHO, 2014; Martin et al., 2011). Medical research throughout the last decades found links between air pollution induced by open fires and various illnesses including pneumonia, chronic obstructive pulmonary disease (COPD), and eye infections, but also stunted growth of children, tuberculosis, and cardiovascular diseases (see Armstrong and Campbell, 1991; Campbell et al., 1989; Dherani et al., 2008; Kan et al., 2011; McCracken et al., 2011; Pandey, 1984a,b; Pandey et al., 1989). Furthermore, biomass usage for cooking is a major source of climate-relevant emissions (Shindell et al., 2012).

Improved biomass cooking stoves (ICSs) are often believed to be a game changer for cooking in developing countries. It is in this context that the United Nations set out the Sustainable Energy for All initiative with the ambitious goal of globally universal adoption of clean cooking stoves and electricity by 2030. There is, however, a wide range of ICSs with different levels of sophistication that have

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strong implications for smoke emissions and thus cleanliness. It is hence still a matter of ongoing debate under which conditions ICSs can be considered as clean, also compared to modern fuels like electricity and gas.[1]

This paper presents findings from a Randomized Controlled Trial (RCT) among 253 households in twelve villages in Senegal to analyze behavioural responses and impacts following the introduction of an ICS. The ICS, which was assigned free of charge, is a low-cost and maintenance-free portable clay-metal stove. It is produced in a fairly standardized way by local manufacturers (potters and whitesmiths) in their workshops and is marketed at a retail price of around 10 US$. The stove has an expected life span of one to three years before it deteriorates and has to be replaced. It has already been widely used in large governmental dissemination programmes in urban and rural Africa. As such, this is the first study to assess a type of ICS whose design is geared towards fuel savings, ease of use, affordability and, hence, large-scale applicability, but one that lacks specific health-conducive technical features such as a cleaner burning process or a chimney. Without further changes in cooking behaviour, the reduction in particulate matter emissions that the randomized ICS can technically achieve would probably be insufficient to affect the health of users. This is due to the non-linear particulate exposure–response relation found in medical research suggests that large reductions in smoke exposure are required in order to ensure positive health effects (see, for example, Ezzati and Kammen, 2001; Pope et al., 2011; Burnett et al., 2014).

The main impact indicators of this study are firewood consumption, time use, respiratory disease symptoms and eye infections. They are supplemented by various indicators along the results chain of the intervention with regard to cooking behaviour. Effects on these indicators were assessed 12 months after randomization following a baseline study in November 2009. The behavioural changes we look at – firewood usage patterns and smoke exposure – can be expected to materialize already in the first few months after ICS adoption. The changes in these indicators we observe after one year of ICS ownership therefore reflect impacts to be expected in the long run – as long as people continue to use the ICS and replace it by a new one once it is not functional anymore. The third wave of interviews in March 2013 is used to track the longer-term usage behaviour and the stove's durability at the end of what technically is the life span of the ICS.

A couple of factors contribute to a high external validity of this RCT for the African context: the study was implemented in an unobtrusive way in order to ensure that we observe real-world cooking behaviour. It was designed and conducted in cooperation with the ICS dissemination programme of the Government of Senegal, so that an upscaling of the intervention under real-world conditions would be possible. Furthermore, the dominating cooking fuel in our study area is firewood, which is also the case in most other African countries (Bonjour et al., 2013). Firewood scarcity in our study region and, consequently, the incentive to use more efficient stoves is pronounced and comparable to other dry areas in non-equatorial Africa.[2]

We find that the ICSs are taken up by virtually all households and intensively used, even after three and a half years. For the most part, people only give up using the stove when it is not functional anymore and not because they lose interest in using it. We furthermore observe substantial effects on firewood consumption, which confirm savings rates determined in lab tests. In addition, we find a decrease in early indicators for respiratory diseases and eye infections. These effects on people's health status cannot be explained only by the take-up of the new ICS and the firewood savings, but rather by an additional reduction in smoke exposure due to more outside cooking and a reduced cooking time that is enabled by the new stove.

Our findings add to the existing body of evidence on ICS impacts, which so far is mainly represented by two RCTs: the RESPIRE study in Guatemala (see, for example, Smith-Sivertsen et al., 2004, 2009; Díaz et al., 2007; Smith et al., 2011) and a study conducted by J-Pal in India (Hanna et al., 2012).[3] Both studies used stationary chimney ICSs that are installed in the user's kitchen, with the difference that the RESPIRE stoves are of higher quality, thus more expensive (100–150 US$), and require less maintenance than those used in the Hanna et al. (2012) study. A more detailed comparison of technical features of the ICSs used in the different studies is provided in Appendix A. While the RESPIRE study detects a substantial reduction in household air pollution and a reduction in the risk of respiratory disease symptoms and eye problems, Hanna et al. observe reductions in smoke inhalation only in the first year but not over a four year time horizon. This is mainly driven by maintenance being more and more neglected over time, which leads to a weak performance and low usage rates after some years.

Against this background, our paper is the first to add evidence on how people use an adapted and simple ICS in an unsupervised setup that is deemed to represent a more realistic study environment than the highly controlled medical trials conducted for RESPIRE. Our study contributes to the literature by providing compelling evidence that such a simpler and cheaper ICS can actually also trigger substantial impacts – if cooking behaviour also changes. Conceptually, these results confirm the findings of Hanna *et al.*: Looking at the technical features of an ICS is not enough, since the real-world behaviour of users strongly co-determines the results. Unlike Hanna et al., though, we find that behavioural adaptations to a simple ICS may trigger sizable positive health effects.

These differences in findings of the two studies show the potentials of disseminating ICS that are adapted to the target population and that facilitate cleaner cooking. The stove used in the Hanna et al. study requires regular maintenance, for which people in turn need to be trained (which not all of them were), while the stove randomized for our study is maintenance-free. Furthermore, our portable stove is well adapted to the local cooking habits, whereas the stove distributed in Hanna et al. interferes more with local cooking habits by requiring people to cook inside, which they are not accustomed to. In this sense, the stove in our study increases the number of choice variables for the users, while the one used in Hanna et al. decreases it.

In this broader behavioural context, our study adds to a nascent strand in the health economics literature studying adoption behaviour of households for health relevant technologies and goods such as bednets (Cohen and Dupas, 2010; Tarozzi et al., 2014), point-of-use drinking water disinfectants (Luby et al., 2008; Kremer et al., 2009), deworming drugs (Kremer and Miguel, 2007), condoms (e.g. Kamali et al., 2003), or a range of such technologies (Wendland et al., 2015). More specifically, it demonstrates

[1] See World Bank (2011) for a more detailed discussion of different types of improved cooking stoves and Martin et al. (2011) for a recent overview on the improved stoves and air pollution policy debate.

[2] External validity and potential challenges to it are discussed further in Section 3.5 and Appendix D.

[3] In addition to these two studies, further evidence with mixed results exists for China (Mueller et al., 2013; Yu, 2011), Mexico (Masera et al., 2007) and urban Senegal (Bensch and Peters, 2013). Burwen and Levine (2012) conducted an RCT in Ghana using a very simple mud stove. As a major difference to the present study as well as the RESPIRE and the J-Pal study, tests in a controlled field lab setting already find that the stove does not perform better than the traditional ones. The poor performance is also reflected in low usage rates after a few months.