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Applying global cost-benefit analysis methods to indoor air pollution mitigation interventions in Nepal, Kenya and Sudan: Insights and challenges

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ABSTRACT

Indoor air pollution from burning solid fuels for cooking is a major environmental health problem in developing countries, predominantly affecting children and women. Traditional household energy practices also contribute to substantial time loss and drudgery among households. While effective interventions exist, levels of investment to date have been very low, in part due to lack of evidence on economic viability. Between 2004 and 2007, different combinations of interventions – improved stoves, smoke hoods and a switch to liquefied petroleum gas – were implemented in poor communities in Nepal, Sudan and Kenya. The impacts were extensively evaluated and provided the basis for a household-level cost-benefit analysis, which essentially followed the methodology proposed by the World Health Organization. The results suggest that interventions are justified on economic grounds with estimated internal rates of return of 19%, 429% and 62% in Nepal, Kenya and Sudan, respectively. Time savings constituted by far the most important benefit followed by fuel cost savings; direct health improvements were a small component of the overall benefit. This paper describes the methodology applied, discusses the findings and highlights the methodological challenges that arise when a global approach is applied to a local programme.

1. Introduction

More than three billion people worldwide depend on solid fuels, including biomass (i.e., wood, dung and agriculture residues) and coal, to meet their basic energy needs such as cooking, boiling water and heating (WHO, 2006). These solid biomass fuels lie at the bottom of the 'energy ladder' (WHO, 2006), and their inefficient combustion releases high concentrations of hundreds of health-damaging pollutants, such as particulate matter (PM) and carbon monoxide (CO). There is abundant evidence supporting the relationship between this indoor air pollution (IAP) and a broad range of health problems, in particular childhood acute lower respiratory infections (ALRI), chronic obstructive pulmonary disease (COPD) and lung cancer (where coal is used) (Smith et al., 2004). Moreover, studies have linked IAP exposure to a variety of other health outcomes, such as low birth weight and stillbirth (Pope et al., 2010), tuberculosis (Slama et al., 2010), asthma, cataracts (Bruce et al., 2000) and high blood pressure (McCracken et al., 2007b). Based on a comparative risk assessment undertaken by the World Health Organization (WHO), IAP is responsible for 1.6 million global deaths and 2.7% of the global burden of disease annually (WHO, 2006). A majority of the population living in the poorest countries of sub-Saharan Africa and South Asia continues to rely on solid fuels, and these countries also shoulder the largest share of the health burden.

A number of technologies are available to solve the IAP problem. Switching from traditional to modern fuels, such as liquefied petroleum gas (LPG), biogas and ethanol, brings about the largest reductions in IAP. In many poor rural communities, however, access to these alternatives is limited by availability and affordability, and biomass remains the most practical fuel. Here, improved stoves – provided they are adequately designed, installed and maintained – can reduce IAP considerably. Stove location, housing construction and better ventilation are also partial remedies. All of these interventions have the potential to deliver a wide range of other benefits for poverty reduction and environmental sustainability.

Despite the critical role household energy use plays for socio-economic development and the magnitude of the health effects, in particular among women and children, the problem has been largely ignored. The reasons are likely to be manifold, including low awareness about the health impacts of IAP among the affected populations and limited availability of locally appropriate and affordable cleaner cooking technologies. One reason for the lack of international recognition is the shortage of evidence on the effectiveness and cost-effectiveness of different solutions and on

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reliable mechanisms for their delivery. Showing that improved household energy interventions can be economically efficient should contribute to stimulating investment nationally and internationally, and to widespread adoption locally.

The present study, carried out in Kenya, Sudan and Nepal, sought to understand how poor local communities could overcome the barriers that prevent them from accessing interventions to reduce IAP. A key output was to analyse the economic viability of various IAP-alleviating technologies using cost benefit analysis (CBA). We adapted the CBA guidelines developed by the WHO to a household perspective in these local settings. This report also describes the challenges that arise when global guidelines are applied and modified in the context of a specific local project, reviews methodological strengths and limitations, and compares findings with those of other CBA studies.

2. Cost-benefit analysis of household energy interventions—a review

Economic evaluation of interventions being considered for wider implementation is of growing importance as a means of demonstrating the return on investments, comparing the efficiency of one intervention against another, and helping policy-makers decide how to allocate limited budgets (WHO, 2002).

The WHO has published guidelines for CBA of household energy interventions (Hutton and Rehfuess, 2006), and has applied these in a global/regional case-study (Hutton et al., 2006). Costs and benefits were modelled under eight different intervention scenarios, covering three technical interventions – LPG, biofuel (ethanol) and a chimneyless stove based on the *rocket* design – at two levels of population coverage, 50% and 100%. The majority of reported benefit-cost ratios (BCRs) were either greater than 1 (signifying that benefits exceed costs) or had negative values that result from intervention cost savings exceeding the intervention costs, for example, where improved fuel efficiency reduces costs of purchased fuel. These analyses showed that, from a societal perspective, investments in household energy interventions can be highly cost-beneficial and, in some cases, cost-saving. Under the model assumptions, improved stoves led to the greatest overall benefit to society.

Few local or programmatic CBA studies of household energy interventions have been conducted to date. Larson and Rosen (2000) studied household demand for the control of IAP and, drawing on existing data from several developing countries, found that the theoretical willingness to pay for control measures is high and considerably exceeds costs. Habermehl (2007) examined costs and benefits for 190,000 households using *rocket* wood stoves and improved charcoal stoves, promoted by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) in Uganda. The reported BCR of 25 suggests that every Euro invested in such interventions yields 25 Euros in return. Finally, Winrock International carried out a CBA of biogas interventions for all of sub-Saharan Africa and country-level analyses for Uganda, Rwanda and Ethiopia (Renwick et al., 2007). The intervention combined household biogas, latrine and hygiene facilities, with an approximate 30% subsidy of the biogas unit cost. This study also found favourable BCRs, ranging from 1.2 to 1.3 for the household perspective, and 4.5 to 6.8 for the societal perspective.

3. Practical action project in Kenya, Sudan and Nepal

3.1. Background

Between 2004 and 2007, Practical Action (then the Intermediate Technology Development Group or ITDG) implemented the research project 'Researching pathways to scaling up sustainable and effective kitchen smoke alleviation' among poor communities in Kenya, Sudan and Nepal (Bates et al., 2007). The project sought to set up an infrastructure for long-term delivery of smoke-alleviating interventions through development of existing social and commercial structures to promote demand, facilitate purchase through credit, and support production. The ultimate aim was for the 'beneficiary' to become the 'customer' and the role of the non-governmental organisation (NGO) to be superseded by the supplier or service provider.

This research (termed hereafter Phase II) was based on an earlier project (Phase I) (Bates et al., 2005), which identified and developed a number of low-cost and no-cost technologies for alleviating IAP in the same communities, working collaboratively with NGOs and local partners. Through focus group discussions and other participatory approaches, the project helped communities to select those interventions or combinations of interventions that they considered most appropriate to their needs and budgets, and developed a set of monitoring methods to determine their effectiveness. The monitoring in Phase I included the following components, carried out over 24 h and repeated on four occasions (twice pre-intervention and twice post-intervention):

- Room concentration of respirable particles ($PM_{3.5}$)[1].
- Kitchen CO concentrations.
- The relationship between 24 h room CO and 24 h room $PM_{3.5}$, which was derived by co-locating the pump and cyclone in approximately 30 houses in each country during each of the 4 rounds (2 pre-intervention and 2 post-intervention).

These Phase I data formed the background to the work described in the current paper.

3.2. Project location

The project (Bates et al., 2007) took place in three settings, each with distinct needs:

- Peri-urban communities in Kisumu, West Kenya, which use wood, charcoal and agricultural residues as their main cooking fuels.
- Communities near the towns of Kassala and New Halfa, Sudan, which use wood and charcoal, and struggle to find fuel due to the large influx of displaced people.
- Rural communities in Rasuwa district, a mountainous region in northern Nepal, which rely on biomass for space heating and cooking.

Details of the study communities, target populations and interventions available are provided in Table 1.

3.3. Interventions selected

Kenya: Most households in Kenya opted for LPG stove sets, comprising a 4.6 kg gas bottle and burner, or smoke hoods (Table 2). Some households also purchased low- or no-cost interventions such as solar cookers, fireless cookers and *upesi*

[1] Particulate concentrations were measured over 24 h using a Buck I.H. pump sampling at 2.2 l/min, a Higgins–Dewell cyclone and 35 mm glass-fibre filters. This produces a 50% particle cut-off at 3.5 mm. The flow rate was checked prior to each house measurement with a bubble calibrator. Filters were pre- and post-weighed in the National Metrology Centres in Nepal and Sudan, and at the University of Nairobi in Kenya (Bates, et al., 2005). The Higgins–Dewell cyclone measures the 'respirable' fraction of small particles, with most materials having an aerodynamic diameter of 3.5 μm or less. The PM concentrations measured are therefore slightly higher than those that would be found for $PM_{2.5}$ and slightly lower than those that would be found for PM_{10}.