Energy Economics 36 (2013) 605–613

Contents lists available at SciVerse ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

Clean fuel-saving technology adoption in urban Ethiopia ☆

Abebe D. Beyene, Steven F. Koch *

Department of Economics, University of Pretoria, Private Bag X20, Hatfield 0028, South Africa

ARTICLE INFO

Article history:
Received 6 July 2011
Received in revised form 14 October 2012
Accepted 3 November 2012
Available online 9 November 2012

JEL classification:
Q41
Q42
Q55
Q56

Keywords:
Improved stoves
Duration analysis
Adoption
Urban Ethiopia

ABSTRACT

The heavy dependence and inefficient utilization of biomass resources have contributed to the depletion of forest resources in Ethiopia, while the use of traditional cooking technology has also been linked to indoor air pollution and poor health. In response, the government and other institutions have pushed for the adoption of new cooking technologies, with limited success. This research examines the reasons underpinning the lack of widespread adoption, via duration analysis, correlating the speed of adoption of Mirte and Lakech cook stoves – two examples of new cooking technologies – in urban Ethiopia to socioeconomic factors. According to the duration analysis, adoption rates have steadily increased over time, while economic factors, such as product price, household income and household wealth, are, for the most part, important determinants of adoption behavior. There is also evidence that the availability of substitute technologies tends to hinder adoption, and that there are large regional differences in adoption rates, suggesting the need for a more detailed regional analysis of adoption decisions.

1. Introduction

According to the International Energy Agency (IEA, 2002), traditional stoves using dung and charcoal are inefficient and emit large amounts of carbon monoxide (CO) and other noxious gases. As a result, poor people in the developing world are constantly exposed to indoor particulate matter and carbon monoxide concentrations many times higher than the World Health Organization (WHO) standards. Surveys by Bruce et al. (2002), Emmelin and Wall (2007), Fullerton et al. (2008) and Smith et al. (2004), summarize the strength of association between indoor air pollution (from, especially, biomass fuel use) and a wide range of illnesses and diseases. Associations are shown to exist for acute lower respiratory tract infection, low birth weight, nutritional deficiency, interstitial lung disease, chronic obstructive lung disease and lung cancer, tuberculosis, cardiovascular disease, and cataracts; similar information can be found in WHO (2006). These health problems tend to be greater where traditional cooking technology is more common (Masera et al., 2007; Smith and Mehta, 2003; Tasleem et al., 2007), such as in Ethiopia.

Ethiopians, like citizens in many developing countries, are highly dependent on biomass energy sources: fuel wood, charcoal, animal dung and crop residues. As noted by Geist and Lambin (2003) and Vance and Iovanna (2006), socioeconomic factors, such as poverty, force people in developing countries, including Ethiopia, to exploit forest resources for both domestic energy consumption and commercial gains. The aforementioned biomass energy sources, according to the Ethiopian Environmental Protection Agency (EPA, 2004), account for more than 90% of total domestic energy demand — approximately 99% of demand in rural households compared to 94% of demand in urban households. Given the high levels of dependence, biomass sources will continue to dominate energy demand in both rural and urban Ethiopia in the foreseeable future.

Ethiopian dependence on biomass fuels impacts on the health of its citizens, especially women and children. The World Health Organization (WHO, 2002) estimates that fumes from indoor biomass fuel use kill 1.6 million women and children in developing countries, each year, accounting for 3% of the global burden of disease. More recent information contained in WHO (2009) suggests that 1.1 million female and 0.9 million male deaths worldwide (0.5 million total in Africa) can be attributed to indoor smoke from solid fuels, such that biomass fuel use contributes 3.3% of the global burden of disease. The figures for Ethiopia, though, given its dependence on biomass fuels, are proportionately worse. According to the WHO (2002) report, with 95% of households using biomass fuels as their primary

☆ We are very grateful to Ato Melesaw Shanko, managing director of MEGEN Power Ltd., and Hiwote Teshome from GTZ for making the data available, as well as to Alemu Mekonnen for helping us connect with these individuals. We gratefully acknowledge their willingness to discuss improved biomass cook stoves in Ethiopia. The authors would also like to thank *Economic Research Southern Africa* for their support of this research. Finally, thanks to the anonymous reviewers for their comments. We believe that their comments have greatly improved this manuscript. Any remaining errors are solely the responsibility of the authors.

* Corresponding author. Tel./fax: +27 12 420 5285.
E-mail addresses: abebed2002@yahoo.co.uk (A.D. Beyene), steve.koch@up.ac.za (S.F. Koch).

0140-9883/$ – see front matter
http://dx.doi.org/10.1016/j.eneco.2012.11.003

energy source, 4.9% of the Ethiopian burden of disease can be attributed to solid fuel use for cooking, heating and lighting; nearly 50,000 deaths can be attributed to the same cause.

In order to mitigate the adverse impact of indoor air pollution and reduce pressure on forests, the Ethiopian government has devised a number of strategies. Of particular relevance to this research is the promotion of alternative modern fuels and support for improved biomass cook stoves (Cooke-St. Clair et al., 2008). The Lakech and Mirte stoves, discussed below, are two such examples. The realization that improved cook stove technology has the potential to alleviate the pressure on biomass resources and improve health led to improved cook stove programs in a number of developing countries, including Ethiopia.[1] Similarly, a number of institutions, e.g., the Ethiopian Rural Energy Development and Promotion Center (EREDPC), and other organizations, such as the German Technical Corperation (GTZ), have been involved in the development and dissemination of different types of biomass cook stove technologies since the early 1970s in Ethiopia (EPA, 2004). Most recently, in December of 2010, the US EPA and the US Peace Corps signed a Memorandum of Understanding (MoU), and that MoU included support for the Global Alliance for Clean Cook Stoves in Ethiopia.[2]

Unfortunately, as discussed in Barnes et al. (1994) and Shanko et al. (2009), the efforts to disseminate various types of fuel-saving technologies have faced different problems at different times. For example, some of the stove programs were not successful, due to problems related to the stove itself (technical problems). Other programs were not successful, due to a lack of understanding of consumer tastes, while some programs were not successful, due to the lack of an appropriate promotion strategy. In addition to implementation problems, there are real concerns that the expected forestry benefits may not obtain. Specifically, the rebound effect – intuitively, better technology results in a decrease in the price of inputs yielding scale effects – has been observed in a number of locations. Nepal et al. (2010), for example, find that improved cook stoves in Nepal do not yield reductions in the demand for firewood. Sorrell et al. (2009) provide a more detailed review of literature in relation to the rebound effect.

Although it is not clear that new cook stove technology will alleviate forest dependence, there is a strong evidence of significant potential health benefits for households that adopt improved cooking technology. Given the expected household benefits, the failures of earlier programs and the renewed emphasis on invigorated promotion efforts, an examination of adoption decisions at the household level deserves attention. However, most available studies related to technology adoption, especially those related to improved biomass cook stove technologies – Amacher et al. (1992), Gebreegzihabher et al. (2005) and Jan (2012) – have focused only on the dichotomous decision to adopt new technologies, and have not considered the timing of adoption. Although informative, these binary analyses are static and ignore the dynamic nature of the adoption process. Furthermore, the aforementioned studies have focused on rural households. Therefore, this research makes two contributions to the literature.

First, the available limited studies focus on rural areas, such that the urban sector is under-represented. However, the high dependence of urban dwellers on biomass resources also contributes to environmental and health problems. For example, charcoal, the production of which is one of the main causes of deforestation in Ethiopia, is almost exclusively used in urban areas, irrespective of the level of living standards. Moreover, since many households cannot afford modern energy sources, such as kerosene, liquefied petroleum gas (LPG) and electricity, a substantial portion of the urban poor will continue to rely on fuel wood and charcoal. Therefore, focusing on urban households is useful, from the viewpoint of protecting forest cover, as well as reducing the ill effects of biomass fuel use on health.

Second, the commonly applied binary dependent variable analysis, which considers only adoption or non-adoption, does not account for adoption over time, since it does not allow for differences in the time to adoption by the households. This analysis, therefore, employs duration analysis, rather than static analysis, and, as far as we are aware, is the first to do so, within the context of improved cook stove technology adoption. The main objective of this research is to examine and understand the determinants of the speed of adoption of fuel-saving technologies, especially for Mirte and Lakech cook stoves, in urban Ethiopia. Though many factors, such as the technical design of the stove, are likely to affect the speed of adoption, the data available for this study allows us only to address socioeconomic factors associated with the dissemination of improved biomass cook stoves in urban Ethiopia.

For the analysis, a series of proportional hazard models are estimated to examine the timing of the adoption of improved biomass cook stoves, based on data collected amongst urban households in Ethiopia. The timing of adoption is, unfortunately, based on recall data collected at one point in time, rather than on panel data collected over time, which would have been preferred, since recall is rarely perfect. Importantly, it was possible to include price information from the year of adoption to control for some changes that occurred in the market for improved biomass cook stoves in Ethiopia. However, the rest of the variables are time-invariant, and generally collected post-adoption, due to the nature of the survey. The results of the analysis point to adoption rates that increase over time, as well as economically appealing price and income effects – demand curves are downward sloping and cook stoves are normal – however, the economically appealing results are not statistically significant in all cases.

The analysis unfolds in the usual fashion. The next section outlines the empirical methodology. Section 3 discusses the stove technologies examined in the analysis, as well as the survey data used for the analysis. The variables used in the analysis, as well as the literature underpinning the choice of these variables, receive special attention in this section. The results of the empirical analysis are presented in Section 4, while Section 5 concludes.

2. Methodology

The analysis of duration data, commonly referred to as survival analysis, has been applied in a number of situations in economics, demography and medicine. In terms of medical research, the focus is often on patient survival following either disease diagnosis (Brookmeyer et al., 2002) or the administration of a medical treatment (Locatelli et al., 2001). In demography, survival analysis is often applied in the examination of mortality rates and relates to the length of time a child survives from birth, or the time that a mother survives following childbirth; some examples include Abou-Ali (2003), Handa et al. (2010) and Lavy et al. (1996). Within economics, unemployment duration and the duration of strikes have often been examined via duration models, such as Kennan's (1985) and Jaggia's (1991) analyses of strike duration in the US manufacturing sector. Most relevant to this study, though, is the analysis of technology adoption – Burton et al. (2003), Dadi et al. (2004), and Fuglie and Kascak (2001) – and Lee's (2003) adoption of privatization policy. Burton et al. (2003) suggest that duration analysis has strengths compared to the conventional bivariate outcome models, since simple bivariate outcome models cannot capture the inter-temporal nature of the adoption process. Under these circumstances, the use of duration models is superior to the analysis of adoption at any one point in time.

Survival analysis depends primarily on the distribution of durations, or the length of survival times, in the population. Following the standard formulation, let $T \geq 0$ denote the duration, while t denotes a particular value of T. In our case, duration is the length of time, measured in years, until the household adopts the new technology; the formulation of this measure is described below. The

[1] Barnes et al. (1994) provide an excellent survey of the programs put in place before 1994, as well as the lessons that could be learned from those programs, while Bhattacharya and Abdul-Salam (2002) provide a detailed description of programs in India and China.

[2] In addition, Ethiopia's Climate-Resilient Green Economy (CRGE) document (EPA, 2011) includes a plan to distribute up to 9 million improved stoves by 2015, in order to reduce GHG emissions from fuel wood consumption.