Energy Policy 86 (2015) 393–401

Contents lists available at ScienceDirect

Energy Policy

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

Using contingent behavior analysis to measure benefits from rural electrification in developing countries: an example from Rwanda

Dale T. Manning [a,*], Peter Means [b], Daniel Zimmerle [c], Kathleen Galvin [d], John Loomis [e], Keith Paustian [f]

[a] Colorado State University, Department of Agricultural and Resource Economics, USA
[b] Colorado State University, School of Global Environmental Sustainability, USA
[c] Colorado State University, Energy Institute, USA
[d] Colorado State University, Department of Anthropology, USA
[e] Colorado State University, Department of Agricultural and Resource Economics, USA
[f] Colorado State University, Department of Soil and Crop Sciences, USA

HIGHLIGHTS

- A lack of electricity slows economic growth in rural villages of Sub-Saharan Africa.
- Household survey provides data on potential electricity use in Rwandan villages.
- Contingent behavior analysis estimates total economic surplus from electricity.
- Household electricity bills estimated to calculate investment returns.
- Investment in rural electrification likely to bring positive benefits to rural Rwanda.

ARTICLE INFO

Article history:
Received 6 December 2014
Received in revised form
17 June 2015
Accepted 18 June 2015

Keywords:
Rural Energy
Electricity access
Stated preferences
Contingent behavior
Rural economic development

ABSTRACT

Hundreds of millions of people in Sub-Saharan Africa do not have access to electricity and will not receive it from national grids in the next few decades. Electricity makes up an important component of rural development and so increasing access can have positive socioeconomic benefits. In this study, we use contingent behavior analysis to quantify the potential benefits of electricity in rural Rwandan villages which currently do not have electricity. The proposed method allows for calculation of net benefits as well as electricity bills. We find that even relatively poor, isolated households would pay for electricity, though amounts vary across households and this affects the financial viability of electrification. Common uses for electricity include lighting, battery charging, and agricultural processing. Despite heterogeneity, opportunities exist to improve rural economic welfare through increased electricity access.

1. Introduction

Six hundred million people in Sub-Saharan Africa have no access to electricity (Lee et al., 2014). Without electricity for light and battery charging, households use candles and kerosene lighting which increase mortality and sickness associated with indoor air pollution. Charging phones involves time-consuming travel and high costs to rent access to electricity. The lack of access to electricity slows economic development through negative impacts on income, health, education, and labor productivity (Lipscomb et al., 2013, Khandker et al., 2012, Khandker et al., 2013, Kooijman-van Dijk and Clancy, 2010). As a result, a benefit to increasing electrification in rural areas likely exists.

In response to low levels of rural electrification, development agencies and governments have identified rural electrification as an important component of economic development (I. E. G, 2008). Nevertheless, a large part of Sub-Saharan Africa will not receive grid-connected electricity because of high costs. Globally, it is estimated that 1.4 billion people will lack access to electricity by 2030 (Kanagawa and Nakata, 2007, from IEA World Energy Outlook), of which over half will be in Sub-Saharan Africa (SE4All Global Tracking Framework). In Rwanda, the national target is to

* Corresponding author.
E-mail addresses: dale.manning@colostate.edu (D.T. Manning), ptmeans@gmail.com (P. Means), Dan.zimmerle@colostate.edu (D. Zimmerle), Kathleen.galvin@colostate.edu (K. Galvin), john.loomis@colostate.edu (J. Loomis), keith.paustian@colostate.edu (K. Paustian).

http://dx.doi.org/10.1016/j.enpol.2015.06.032
0301-4215/

electrify ~70% of the population by 2018, with 48% reached through grid expansion (Rwandan Ministry of Infrastructure, 2014). To meet the remaining demand, policymakers and entrepreneurs have begun to search for technologically and economically viable alternative methods to deliver electricity. These include diesel generators, micro grids (Soshinskaya et al., 2014), household-specific solar panel units (Samad et al., 2013, Bensch et al., 2013), and micro-hydro projects (Maher et al., 2003, Kaundinya et al., 2009).

While much effort has focused on technological innovations to increase access, access alone may not be sufficient to stimulate economic growth (Foley, 1992). Therefore, information on the demand for technology must inform technological development and institutional frameworks that optimize the use of technical innovations.

The objective of this study is to estimate the net benefit of electricity by measuring total benefits and electricity bills households would pay if electrified. This information can inform infrastructure design and investment in rural electrification in developing countries. Contingent behavior survey responses are used to estimate household-specific electricity demand curves and to divide total benefits into consumer surplus and revenue to an electricity provider. Longer-run benefits, not considered here, are likely larger as households invest in tools and products that require electricity. If electricity use improves local incomes, increases in demand for local goods and services could also have indirect effects. Therefore, our method likely provides lower bounds for the benefits of electricity over time.

The following section provides motivation for the research method employed in this study. The Rwandan context is then described along with the empirical method for measuring electricity demand. Next, results of demand estimation are presented and discussed and results are used to examine the benefits of micro-grid electricity in rural villages. Finally, we conclude by discussing shortcomings of the current study and avenues for future research while highlighting important considerations for investment in rural electricity infrastructure.

2. Research methods

2.1. Stated preferences

Estimating the demand for electricity in remote villages that have never had access presents a challenge. While it is possible to transfer demand functions from electrified villages, there can be significant differences between villages with and without electricity.[1] The difficulty of estimating the benefit of new goods, whether in the consumer market or public goods, has given rise to stated preference methods in economics. Stated preference (SP) relies on stated instead of revealed behavior. For example, the contingent behavior method provides an estimate of what people say they would do contingent upon the description of a good (e.g., its price) in a survey. We make use of this method by asking survey respondents the amount of time they would consume electricity at different prices. In this way, we ask how people would behave contingent upon the price of electricity.

The disadvantage of SP methods comes from the possibility of hypothetical bias (Murphy et al., 2005). Because the questions being asked in the survey do not require respondents to make actual trade-offs, they may lack an incentive to answer truthfully. Survey questions can be framed to increase the incentive for households to carefully consider their responses so as to increase the validity of the answers provided. In rural Rwanda, consumers are familiar with electricity and have a good understanding of its potential uses. While electrification rates are low in Rwanda and even lower in rural areas of Rwanda (1.3% according to the UNDP/WHO in 2009), rural household members regularly travel to electrified market centers. In our study, 80% of the rural households own mobile phones and pay others to charge them. Therefore, households are used to purchasing electricity for a given use. The electricity required for charging a mobile phone differs from electricity consumed by other appliances and devices in the home but phone charging familiarizes households with paying for electricity.

Other well-known biases are present when using SP methods. We have taken steps to minimize each bias but taken together, they mean our results should be interpreted as illustrative. For example, Herriges and Shogren (1996) highlight the importance of ‘starting point’ bias. In our analysis, we provide survey respondents with a list of electricity prices and this list does not vary across households. Respondents are presented this price range and see all prices at once (i.e., as in a showcard). The range of prices provided can in some circumstances influence responses, making it hard to estimate absolute levels of willingness-to-pay (WTP) using SP (Arrow et al., 1993). However, the starting point bias found by Herriges and Shogren was in the context of the double bounded dichotomous choice WTP question format. Our display of prices at which households are asked to indicate the quantity they consume bears more resemblance to a payment card format because all prices appear together. Rowe et al. (1996) found that responses to the payment card format were not sensitive to the range or center of the monetary amounts shown on the card.

Transferring existing estimates of electrification benefits is risky because of differences across villages. Rosenberger and Loomis (2003) find that transferring benefits across settings can result in errors of up to 500%. This means that SP can provide helpful context-specific valuations.

2.2. Public infrastructure benefits in developing countries

Stated preference and choice experiment methods have been used to estimate the value of public goods (Whittington, 1998, Zhongmin et al., 2003) and infrastructure (Abdullah and Mariel, 2010, Perez-Pineda and Quintanilla-Armijo, 2013, Seraj, 2008) in developing countries (Bennett and Birol, 2010). Studies have focused on the benefits from improved infrastructure. For example, Abdullah and Mariel (2010) use a choice experiment to investigate household willingness to pay for improvements in the reliability of grid electricity in Kenya. Abdullah and Jeanty (2011) estimate willingness to pay to connect to a central grid. The analysis presented here builds on this literature to examine the benefits of electricity consumption for non-electrified households.

Several existing studies use observational data on households with and without electricity to estimate the impacts of electricity. For example, Khandker et al. (2012) find that grid connection in rural Bangladesh increases household income by 21%. Khandker et al. (2013) show an increase in total income of up to 28% in Vietnam. In addition, they find that school enrollment rates increased by 8–9% for boys and girls as a result of rural electrification in Vietnam. Dinkelman (2011) finds a positive impact of electrification in South Africa on female labor force participation. In rural Rwanda, it has been shown that rural electrification increases the use of light (Bensch et al., 2011).

While informative, these studies focus on electricity use and impacts in grid-connected rural areas. Fundamental differences across geographic space mean that households in isolated, often

[1] Also, demand for electricity has changed over time as technology changes and electronics become more affordable. Therefore, past studies may not reflect current electricity uses.