Energy Policy 49 (2012) 531–540

Contents lists available at SciVerse ScienceDirect

Energy Policy

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

An assessment of electricity and income distributional trends following rural electrification in poor northeast Brazil

Martin Obermaier*, Alexandre Szklo, Emilio Lèbre La Rovere, Luiz Pinguelli Rosa

Energy Planning Program, Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering (COPPE), Federal University of Rio de Janeiro (Universidade Federal do Rio de Janeiro, UFRJ), Centro de Tecnologia, Sala C-211, Cidade Universitária, Ilha do Fundão, Rio de Janeiro, RJ 21941-972, Brazil

HIGHLIGHTS

- Comprehensive analysis of Brazil's recent rural electrification efforts.
- New methodology to analyze energy and income equity trends *ex post* electrification.
- Analysis indicates immediate social benefits for electrified households.
- We cannot establish a direct link between electricity use and income in the short-run.
- Electrification thus should be integrated in long-term rural development strategies.

ARTICLE INFO

Article history:
Received 25 August 2011
Accepted 27 June 2012
Available online 15 July 2012

Keywords:
Rural electrification
Energy-income nexus
Brazil

ABSTRACT

Rural electrification is considered to be a key strategy for poverty alleviation and sustainable development. It should therefore include (1) *expanding electricity access* and (2) *enable new consumers to increase their electricity consumption*. In this paper we ask how Brazil's recent rural electrification efforts have managed to reach these objectives. A new method to measure energy and income equity is presented which uses estimations of non-parametric density curves for the analysis of energy and income distributional trends following electrification. By applying our method to a panel data set from two Brazilian states situated in the country's poor northeast region we find that (1) rural consumers take up electricity consumption after electrification, and that (2) low consumption levels give way to higher electricity consumption levels after only a few years. This indicates immediate social benefits for households through consumption of electricity services. However, our analysis cannot verify a direct link between electricity use and rural income generation in the short term. The results emphasize the need for government and other actors to integrate rural electrification into broader rural development strategies in order to enable long-term welfare increases through electricity use.

1. Introduction

Rural electrification is a key strategy for poverty alleviation and sustainable development. Due to its versatility and perceived benefits, as well as universal access in most industrialized countries, many individual governments, international donor agencies, and NGOs have since long actively promoted electricity access programs in the developing world (ESMAP, 2000; Karekezi and Kithyoma, 2002; Martinot et al., 2002; Pre Dakar Position Paper, 2008; Niez, 2010).

However, while there is a consensus that electricity access is an essential ingredient for rural development, electric energy itself is not a commodity which can solely alleviate poverty or improve rural living conditions. Instead, the demand for electricity is only derived from the demand for the goods or services it provides or makes possible (Foley, 1995; Wilhite et al., 2000; ESMAP, 2008). Therefore, successful rural electrification programs must simultaneously tackle the issues of (1) *expanding electricity access* and (2) *enable new consumers to increase their electricity consumption*. This latter point integrates concerns to facilitate productive uses of electricity and thus rural development (Munasinghe, 1987; Ranganathan, 1993) as well as social demands for electricity services (including comfort and convenience) and their evolution (Wilhite et al., 2000). It is particularly relevant point as electricity consumption in many developing countries continues to be at extremely low levels even when electrification has reached rural villages (Heltberg, 2004; Fugimoto, 2005; IEA, 2009).

In this context, Brazil has made considerable progress in advancing rural electricity access, and the country is currently near universalization of rural electrification (Goldemberg et al., 2004;

* Corresponding author. Tel.: +55 21 2562 8760; fax: +55 21 2562 8777.
E-mail address: martin@ppe.ufrj.br (M. Obermaier).

0301-4215/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enpol.2012.06.057

Obermaier, 2005; Rosa et al., 2006; Niez, 2010; MME, 2011). Importantly, the Brazilian electricity sector regulations integrate the provision of affordable electricity to low-income consumers so that rural electrification can indeed promote development and satisfy social demands.

However, little empirical work has been carried out in Brazil that could verify these relationships. Aggregate studies at the national level have found electricity consumption to positively influence GDP growth (Obermaier, 2006; Yoo and Kwak, 2010), but it is unclear how this translates into local benefits.[1] Recent studies have discussed electrification efforts in Brazil focusing on broader energy poverty concepts (Pereira et al., 2011) or electricity affordability through a more theoretic lens (Winkler et al., 2011). While these studies affirm an important role for electricity regarding rural development and social benefits, there continues to be a lack of detailed case studies that analyze how electricity consumption progresses following rural electrification (that is "*are new consumers enabled to increase their electricity consumption*"?). Furthermore, few studies have yet analyzed how electricity consumption can be related to welfare gains in rural communities. In this paper we thus specifically ask:

1. How does rural electricity consumption evolve following rural electrification, and does it generate measurable impacts on rural income generation or social benefits among the connected households?
2. How can we measure these trends among rural consumers?

These questions are addressed from an energy equity perspective (Schaeffer et al., 2003; Jacobson et al., 2005; Obermaier, 2009) recognizing that rural electrification is only successful if the poor and excluded can benefit from the connections. The analysis is based on a comparison of electricity consumption and income trends following electrification of over 400 rural households in two Brazilian states, Bahia and Ceará. Both lie in the country's poor northeast region (Silveira et al., 2007; IBGE, 2009) and thus make up for an appropriate case regarding our research questions. Non-parametrical density curves are introduced as a statistical tool to identify electricity and income distributional trends *ex post* electrification. These methods have been previously applied in studies on global income distribution (Sala-i-Martin, 2002; Dikhanov, 2005; Edward, 2006), but have also recently been used in a study on energy equity analysis in the state of Bahia (Obermaier, 2009). In general, these papers show that the estimation of non-parametrical density curves can provide more details and allow for a more refined analysis of distributional trends than would be possible under the use of conventional equity metrics such as the Gini coefficients and Lorenz curves. The original analysis of Obermaier (2009) is enhanced here by including a second case study (Ceará) and a control group in order to analyze the impacts of rural electricity consumption on income generation more clearly.

Accordingly, the remainder of this paper is organized as follows: Section 2 presents an overview on the Brazilian rural electrification efforts and development strategies in the poor northeast region. In the following, we describe the methodology and data. Section 3 then presents the estimations and results on electricity and income distributional trends. Section 4 discusses the findings in light of the recent progress in Brazilian electrification as well as the potential limitations of our methodological approach. Some final in Section 5 remarks conclude this paper.

[1] Recent studies show increasing rural family incomes and a significant reduction in rural income inequality. However, much of this evolution seems to be explained by cash transfer programs and old age pensions (Helfand et al., 2009; Araújo and Lima, 2009).

2. Context and methodology

2.1. Overview on Brazilian rural electrification efforts

Governments have often made rural electrification a governmental agenda. This is also the case for Brazil, where as early as during the 1960s the possibility of financial assistance for rural electrification initiatives was discussed, thus marking the beginning of public sector engagement for rural electrification in Brazil. A first national rural electrification program was implemented in 1970, with other initiatives following soon after (Fugimoto, 2005). Despite the fact that significant progress was made during the following years in supplying rural families with electric energy access – including those in lower income classes – connection rates remained on a low level (Beltrão and Sugahara, 2005). Up into the 1990s, rural electrification policies continued to be predominantly implemented at state level through concessionaires using state treasury resources (ESMAP, 2005; Instituto Acende Brasil, 2007a). Other electrification efforts were handled by a number of international donors as well as NGOs that supported or implemented several non-sectorial and decentralized electrification projects. Institutional set-ups and responsibilities varied considerably between these different programs (Goldemberg et al., 2004; ESMAP, 2005; Zerriffi, 2007).

A marked change was introduced with the Brazilian Constitution of 1988 that recognized the distribution of electricity as an essential public service for which the federal government would have to assume full responsibility. Accordingly, electrification works would either have to be carried out directly by state actors or through designated concessions or permits (Goldemberg et al., 2004).[2] Under these new regulations two large federal-led rural electrification programs were soon started: the Energy Development Program of States and Municipalities (PRODEEM) and the Light in the Countryside (Luz no Campo, or short LNC) — were established in 1994 and 2000, respectively. Both programs displayed strong differences from prior rural electrification initiatives in terms of their magnitude and in the technologies applied (Correia et al., 2002). PRODEEM and LNC were coordinated by similar actors: LNC by Eletrobrás[3] under coordination of the Ministry of Mines and Energy (MME),[4] and PRODEEM directly by the MME. Both programs drew from different funding sources: PRODEEM relied on National Treasury Funds and LNC on Global Reversion Reserve (Reserva Global de Reversão, or RGR) loans for utilities (Goldemberg et al., 2004; ESMAP, 2005) that set aside by law about one-fourth of the available resources for low-income consumers in rural areas (ESMAP, 2005).

PRODEEM was started by presidential decree and was to promote off-grid electrification of rural villages. The program was especially set up to provide solar photovoltaic (PV) panels free of charge upon demand from schools, health centers, and other community installations, but excluded rural households. Between 1996 and 2000, the program provided equipment for 3050 villages, and benefited an estimated 604,000 people (ESMAP, 2005). Five years later, in 1999, the LNC program was implemented with the aim of bringing electricity to 4.4 million people (about 930,000 households) by 2002. Unlike PRODEEM,

[2] Service providers are mainly concessionaires and permissionaires (permit-holders) authorized by ANEEL. Generally speaking, permit-holders are independent operators that work inside a concession area. Rural electrification cooperatives can become permit-holders if they provide a public service (ESMAP, 2005).

[3] The federal-owned holding company for electricity assets, controlling a large part of electric power generation and transmission systems mainly through six subsidiary companies, as well as some distribution capacity in the Amazon area.

[4] The MME oversees the whole power sector and is responsible for policy setting.