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World Development Vol. xx, pp. xxx–xxx, 2016

http://dx.doi.org/10.1016/j.worlddev.2016.08.003

Does Large-Scale Infrastructure Investment Alleviate Poverty? Impacts of Rwanda's Electricity Access Roll-Out Program

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Summary. — The objective of the United Nations Sustainable Energy for All initiative (SE4All) is to provide electricity by 2030 to the 1.1 billion people in developing countries that hitherto lack access. The OECD/IEA quantifies the investment requirements of this to be at 640 billion USD. Little evidence exists on socio-economic impacts of electrification. The present paper is the first to causally investigate the effects of electrification in Africa on all beneficiary groups. The electrification program under research, the Rwandan Electricity Access Role-Out Program (EARP), is one of the largest in the world. Our analysis is based on a panel of 974 households, a full-census survey among health centers, and qualitative surveys among 83 micro-enterprises and 50 schools. We find that EARP has been remarkably effective in increasing the connection numbers among all beneficiary types. Around 3.5 years after electrification, the quantity of consumed electricity and the uptake of appliances, though, remain low. Noteworthy impacts are decreasing energy expenditures and a considerable reduction in dry-cell battery consumption with potential environmental benefits. Beyond this, electricity mostly facilitates people's life, but there is only weak evidence for impacts on classical poverty indicators such as income, health, and education. We conclude by calling for more research on the comparison of on-grid and off-grid electrification with respect to impact potentials, costs, and people's willingness to pay in order to inform the way forward within the SE4All endeavor.

Key words — energy access, difference-in-differences, electrification, mixed-methods, Sub-Saharan Africa

1. INTRODUCTION

More than 1.1 billion people in developing countries lack access to electricity. Some 590 million of them live in Africa, where the rural electrification rate is particularly low at only 14% (SE4All, 2015). It is often hypothesized that a lack of access to electricity hampers human development in many regards. For example, a lack of modern lighting in households is believed to limit their possibilities to pursue not only productive activities after nightfall, but also educational and recreational activities. Likewise, enterprise development and the provision of public services like health care and schooling are difficult. Based on such assumptions, the United Nations are pursuing the goal of universal access to electricity by 2030 via their initiative Sustainable Energy for All (SE4All, see also UN, 2010). The investment requirements of electrification are enormous – IEA (2011) quantifies the additional needs at 640 billion USD if universal access to electricity is to be achieved by 2030. For Sub-Sahara Africa alone, an annual amount of around 19 billion USD is required. In comparison, the total official development assistance influx to Sub-Sahara Africa is 42 billion USD per year (World Development Indicators, 2014).

In spite of these high costs, there has been little evaluation done of the investments into electrification in terms of their socio-economic impacts (Bernard, 2012; Köhlin, Sills, Pattanayak, & Wilfong, 2011). The present paper is the first to causally investigate the socio-economic effects of electrification in Africa on all rural beneficiary groups: households, firms, health centers and schools. The electrification program under research, the Rwandan Electricity Access Role-Out Program (EARP), is one of the largest in the world and intends to drastically boost the electrification rate in the country from six percent in 2009 to 70% in 2017.

There are only few studies that examine the causal relationship between electrification and indicators for household well-being. For Bangladesh, Vietnam and India, respectively, Khandker, Barnes, and Samad (2012, 2013), and van de Walle, Ravallion, Mendiratta, and Koolwal (2015) find evidence for positive effects on household income, educational performance and job market indicators. Parikh, Fu, Parikh, McRobie, and George (2015) find positive effects in particular for women from infrastructure provision, including electricity, in Indian slums on literacy, income and health. Grimm, Sparrow, and Tasciotti (in press) show that electrification contributes substantially to the fertility decline in Indonesia, and Peters and Vance (2011) find comparable evidence for Côte d'Ivoire. For effects on productivity, firm performance and employment, the results in the literature are mixed, with some very positive evidence from India, Kenya, Nicaragua, and South Africa (Dinkelman, 2011; Gibson & Olivia, 2010; Grogan & Sadanand, 2013; Kirubi, Jacobson, Kammen, & Mills, 2009; Rud, 2012) and rather sobering findings from remoter areas in Africa (Bernard, 2012; Grimm, Hartwig, &

* The data underlying this research were collected for an impact evaluation commissioned by the Policy and Evaluation Department of the Ministry of Foreign Affairs of the Netherlands (IOB). We thank Leo Czajka and Leonce Röth for supervising the field work. We are grateful for valuable comments by Christoph M. Schmidt and participants of the Environment for Development (EfD) workshop in Addis Abeba as well as the Center for the Study of African Economies (CSAE) conference in Oxford. Lenz, Peters, and Sievert gratefully acknowledge the support of a special grant (Sondertatbestand) from the German Federal Ministry for Economic Affairs and Energy and the Ministry of Innovation, Science, and Research of the State of North Rhine-Westphalia. Final revision accepted: August 2, 2016.

Please cite this article in press as: Lenz, L. *et al.* Does Large-Scale Infrastructure Investment Alleviate Poverty? Impacts of Rwanda's Electricity Access Roll-Out Program, *World Development* (2016), http://dx.doi.org/10.1016/j.worlddev.2016.08.003

Lay, 2013; Neelsen & Peters, 2011; Peters, Vance, & Harsdorff, 2011). No evidence exists on the effects of electrification on schools or health centers.

Our analysis is based on different surveys which we conducted during 2011–15. The core is a two-period panel of 974 households in 44 rural communities of EARP target areas, surveyed in 2011 and 2013. We furthermore visited a subset of households in these communities for a usage tracking survey in 2015. In addition to this, we established a full census panel among all health centers in the country. These large quantitative surveys are complemented by qualitative surveys among households, micro-enterprises, schools, and health centers. Thus we draw a uniquely comprehensive picture of the various transmission channels via which socio-economic effects of electrification might unfold.

We first study the connection behavior and electricity consumption patterns of households. Using a difference-in-differences identification strategy we examine the socio-economic outcomes education, income, and health as indicators for human development. Second, based on our qualitative case study information from the micro-enterprise survey we explore the effects of electrification on appliance uptake and on productive processes in rural firms. Third, we examine the effects of electrification on health centers and schools. Connecting health centers to the grid is one of EARP's key objectives. We therefore investigate the connection status of all health centers in the country and the extent to which connections have led to an increased uptake of electrical appliances. In addition, we analyze open interview and case study information from our qualitative survey among a smaller number of health centers and schools (results on the school survey are presented in Electronic Appendix 1).

2. CONTEXT

With 11.5 million inhabitants and an area of 26,338 [1] km^2, Rwanda is the most densely populated country in Africa. After recovery from the genocide that devastated the country in 1994, Rwanda is now firmly on the path of resurgence and economic development. At current prices, per capita GDP in 2012 was USD 1,500 (PPP) and in recent years the country recorded an annual GDP growth rate between seven and eight percent (in real terms) against an annual population growth rate of around 2.6%. [2] Notwithstanding this recent growth performance, 44.5% of Rwandans were living on less than two USD a day in 2011 (World Development Indicators, 2014).

The objective of the Rwandan Government is to transform the country into a middle-income country and increase GDP by a factor of four by 2020 compared to 2000. This shall be achieved by private sector development, infrastructure development, and the transformation from an agricultural based economy to a knowledge based economy. [3]

On the electricity demand side, before EARP started in 2009, only about six percent of all households and only one percent of rural households had access to electricity, making it a country with one of the lowest electrification rates in the world. [4] On the supply side, installed electricity generation capacity increased from 69.5 MW in 2007 to 188 MW in 2016 (GoR, 2012; REG, 2016). A huge investment program is expected to further increase the installed capacity up to 563 MW in the coming years (GoR, 2012), supported by an upgrade of the existing interconnections with the neighboring countries. [5]

The Electricity Access Roll-Out Program (EARP) is the central effort of the Government of Rwanda (GoR) to combat low electrification rates. EARP is implemented by the national Rwanda Energy Group (REG) which is also responsible for the generation of electricity, the transmission and distribution, and the connection of customers. [6] EARP is supported by donors and endowed with a budget of USD 377 million for the first phase [7] and at least USD 300 million for the second phase. [8]

During the first phase from 2009 to 2013 EARP aimed at an increase in the national electrification rate from six percent to 16%. By mid-2013, 370,000 connections had been made, implying that the program target has been achieved. [9] The EARP strategy placed special emphasis on connecting social infrastructure: by 2012, all health centers, all administrative offices, and 50% of schools were supposed to be connected (Castalia, 2009, p. 5ff). According to official statistics by May 2013, 36% of schools, 56% of health facilities, and 58% of administrative offices were connected. In total, 170,000 km of transmission and distribution lines were constructed or rehabilitated by May 2013. [9]

The target for the second phase is a national access rate of at least 70% by 2017 and the connection of all remaining health centers, hospitals and administrative offices as well as at least 80% of schools. [10]

3. EVALUATION APPROACH

(a) *Theory of change*

In theory, grid electrification can affect the welfare of people through various channels. If a community is newly connected, households, firms, and social institutions such as schools and health centers can obtain a connection. Since this is still associated with connection costs (fees plus in-house wiring), not all of them might do so. In a next step, the beneficiaries obtain appliances, beginning with electric lamps. Other household appliances typically bought in rural Africa are televisions, radios and mobile phones. Firms may invest in machinery, refrigeration or entertainment appliances. Health centers may use lighting or simple appliances for diagnosis and treatment. Schools can use lighting for evening classes and offer computer courses. [11]

These different beneficiaries can then use electricity for different activities, which in turn can increase productivity and income in the case of firms and improve services provided by health centers and schools. Households' utility may benefit directly from improved lighting quality and access to information, [12] for example, or indirectly via improved services of firms, health centers, and schools. Figure 1 summarizes these transmission channels from electrification to an increase in people's well-being in a stylized presentation. [13]

(b) *Identification strategy*

Impacts among the different beneficiary groups are examined applying different identification strategies. The focus of our paper is on assessing the program's effects on households. The major challenge in evaluating an on-grid electrification program such as EARP is the selection into treatment that happens on two levels. First, on the community level where certain types of communities are given priority by EARP to be chosen as a treatment community, for example those that exhibit better business opportunities. Second, once the community is connected, households self-select into treatment.

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