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Geographic and socio-economic barriers to rural electrification: New evidence from Indian villages☆

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ABSTRACT

The International Energy Agency estimates that more than a billion people remain without household electricity access. However, countries such as India have recently made major progress in rural electrification. Who has benefited from these achievements? We focus on 714 villages in six energy-poor states of northern and eastern India to investigate trends in electricity access. We use data both from the 2011 Census of India and an original energy access survey conducted in 2014 and 2015. During the three years that separated the surveys, distance to the nearest town and land area lose their power as predictors of the percentage of households in the village that has access to electricity. In this regard, the Indian government's flagship rural electrification program seems to have managed to overcome a major obstacle to grid extension. On the other hand, socio-economic inequalities between villages related to caste status and household expenditure remain strong predictors. These findings highlight the importance of socio-economic barriers to rural electricity access and alleviate concerns about remoteness and population density as obstacles to grid extension.

1. Introduction

The lack of electricity access is a major obstacle to socio-economic development (Cabraal et al., 2005; Cook et al., 2005; Bernard, 2010; Dinkelman, 2011) and to this date, more than a billion people in developing countries remain without household electricity access (International Energy Agency, 2014). There are signs of progress, however. Between 2002 and 2012, the percentage of households with electricity access increased from 64% to 76% worldwide (International Energy Agency, 2014). In India, census data show that the percentage of households with electricity access increased from 56% to 67%; even in rural areas, where electricity access is a more severe problem, electricity access increased from 43.5% to 55.3% (Government of India, 2011). However, these encouraging patterns hide considerable variation across villages. Who has benefited from India's rural electrification drive? Who remains without power? How have these improvements been achieved?

The goal of this article is to investigate patterns of rural electrification in India. By conducting the analysis, we provide new insights into why and how certain rural communities but not others have come to enjoy improved rates of electricity access. Using data from the 2011 Census of India and an original survey with 8568 respondents conducted in 714 villages in 2014 and 2015, we examine the role of geographic and socio-economic factors in rural electrification.[1] Our primary outcome variable is the percentage of households electrified within each village. The analysis focuses on six states (Bihar, Jharkhand, Madhya Pradesh, Odisha, Uttar Pradesh, and West Bengal) in northern and eastern India. As these six contiguous states have high levels of energy poverty relative to other states and are inhabited by a population of almost 500 million people, understanding the progress of rural electrification within them is central to understanding India's overall progress toward universal electricity access and service. While other states also face the challenge of rural electrification, these six states contained the largest numbers of non-electrified households at the time of the survey. We also exploit data on the implementation of India's flagship rural electrification program, the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), to evaluate the role of public policy in improvements in electricity access. By explicitly linking improved electricity access and national policy, we can see to what extent government policy has contributed to enhanced rural electrification.

The results of the statistical analysis show that geographic inequal-

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[1] From the census we use only observations corresponding to the villages present in the original survey, that is 714 villages.

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ities of electricity access have significantly decreased since the 2011 census. In the three years before the original survey, distance to the nearest city and the surface area of the village have lost almost all of their predictive power for the percentage of household electricity access. When we use the 2011 census data, these variables are strong predictors of the percentage of electrified households; when we use the more recent data, they no longer predict rates of electricity access. The distribution of electricity access has become more even across the territory as many more remote rural communities now enjoy improved rates of access. This trend can probably be jointly explained by India's rural electrification policy and continued economic growth in rural areas.

On the other hand, inequalities between villages remain stark with respect to wealth and caste composition. Both in the 2011 census data and in the 2014–2015 survey, there is a large difference in electricity access between villages populated by upper and lower caste households. In both samples, the number of upper caste households is a strong predictor of electricity access, whereas the number of lower caste households is either not correlated with electricity access in the village (in the 2015 survey) or its coefficient is about half the size the one for upper caste (in the census data). Similarly, access to electricity across villages continues to be highly dependent on average expenditure within villages, despite the RGGVY's emphasis on providing free connections to households below the poverty line. It is possible that RGGVY prioritized households below the poverty line within villages that are not the poorest. In any case, the provision of free connections appears not to have changed a reality in which the wealthier villages enjoy much better access than their poorer counterparts. Analysis of household data within villages also shows that even controlling for household wealth, lower caste households are about 15% points less likely to have an electric connection than upper caste households living in the same village. Finally, we find evidence for a strong relationship between the quality of electricity service, measured as hours of electricity available on a daily basis, and wealth at the village level.

These results support the idea that India's recent rural electrification drive has been successful in bringing electricity to remote and small rural communities. Rates of electricity access have increased significantly and, after more than half a century of independence, universal electrification is in sight. Neither distance to the closest town nor the geographic area of a village predicts electrification rates today. At the same time, there remains a gap between upper and lower castes, as well as wealthy and poor areas. In this regard, the next frontier for India's electrification effort should be to reduce inequalities of electricity access with respect to social and economic characteristics. The literature on rural electrification has consistently emphasized that small and remote communities face difficulty in gaining access to the national electric grid (Sinha et al., 1991; Mahapatra and Dasappa, 2012; Urpelainen, 2014; Slough et al., 2015), and many scholars have called for increased attention to off-grid alternatives to grid extension (Kaundinya et al., 2009; Kumar et al., 2009; Alstone et al., 2015). Our findings on recent progress in grid extension suggest that in the Indian context, the government has managed to overcome the limitations of grid extension. Instead, the primary challenges appear to be in overcoming limitations related to socio-economic inequity and rural poverty.

The primary contributions of our study are twofold. First, we reach beyond income as a factor explaining variation in rural electrification and consider geographic and social factors. Studies such as Khandker et al. (2012) show a strong relationship between income and energy poverty in India, as the poorest households can only afford a minimal level of energy access, while (Alkon et al., 2016) find evidence of a high willingness to pay for modern energy in rural India, provided modern fuels are available. Golumbeanu and Barnes (2013), in turn, find that high household connection charges are a key obstacle to improved electricity access in Sub-Saharan Africa. At the macro level, Onyeji et al. (2012) consider the role of geography – in particular, population density – in explaining electricity access in Sub-Saharan Africa. While some studies (Oda and Tsujita, 2011) have considered social factors, such as the religious composition of villages in Bihar, as possible explanations for variation in rural electrification, ours is the first one to systematically examine the role of geography and society in rural electrification in a large, energy-poor area of India.

Second, we offer a dynamic picture of the role of these factors in rural electrification. Most studies explaining rural electrification and energy acccess (e.g., Oda and Tsujita (2011); Khandker et al. (2012); Onyeji et al. (2012)) are cross-sectional in nature. While they provide a snap shot of the extent and determinants of rural electrification at a given time, they do not show how the covariates of rural electrification have changed over time. Our findings show that although India's recent rural electrification drive has rapidly reduced geographic disparities in rural electrification, it has done much less to reduce disparities related to income or social status. This dynamic focus is particularly useful for informing policy implementation, as it allows us to describe and explain variegated progress in rural electrification.

2. Rural electrification in India

India's rural electrification situation has improved over time, but large numbers of rural households remain without a connection. The distribution of electricity access across Indian states in 2001 and 2011 is illustrated in Fig. 1. According to the Census of India, between 2001 and 2011, the percentage of households using grid electricity as their primary source of lighting increased from 55.8% to 67.2% (Government of India, 2011). However, the situation is significantly worse in rural areas where, in 2011, only 55.3% of households used grid electricity as their primary source of lighting; at the same time, 92.7% of urban households did so.

In the past decade, RGGVY has been the government's flagship rural electrification program.[2] Since April 2005, the government's goal has been to electrify all unelectrified villages in India, with the exception of a very small number of the most remote villages covered under a separate village electrification program. Besides unelectrified villages, RGGVY also operates in villages with poor electric infrastructure under a modality called “intensive electrification.” Under the scheme, the central government covers 90% of the capital cost, while states are expected to contribute 10%. States must submit an application to the central government for RGGVY funds, commit to implementation, and propose a plan for doing so. State electric utilities then prepare plans for electrifying villages according to RGGVY guidelines, and quality of implementation is monitored both by the Ministry of Power and independent auditors. Any village with a population of 100 or more people is eligible for electrification. Furthermore, the RGGVY offers free household connections to households below the poverty line and considers 6 h per day a minimum requirement of supply. According to official government sources, by August 2015, RGGVY had reached 111,000 previously unelectrified villages and provided connections to 22,300,000 households below the poverty line.[3] This is a large number relative to the total number of villages in the 2011 census (640,000 in total; 600,000 inhabited), especially given that many of these villages in the wealthier parts of India were already fully electrified before the RGGVY began.

We examine the status and trends of rural electrification in six energy-poor areas of north India, with a particular emphasis on spatial and socio-economic determinants of rural electricity access. As for spatial factors, we consider both the distance between the village and the nearest city (logarithmized, kilometers) and the surface area of the village (logarithmized, hectares). These variables form the baseline for

[2] See summary at http://rggvy.gov.in/rggvy/rggvyportal/rggvy_glance.html (accessed October 25, 2015).

[3] See http://rggvy.gov.in/rggvy/rggvyportal/statewisesummary.jsp for progress reports for India and each individual state (accessed October 25, 2015).