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Scaling up finance for off-grid renewable energy: The role of aggregation and spatial diversification in derisking investments in mini-grids for rural electrification in India

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ABSTRACT

Today, about 1.1 billion people lack access to electricity worldwide. It is estimated that annual investments of 48 billion USD are required to meet the target of the Sustainable Development Goals of providing universal electricity access by 2030. The need for private investments to meet this target is evident, but small-scale electrification projects are often unattractive for private investors due to unfavourable risk-return profiles and small investment volumes. Both issues can potentially be addressed by aggregating projects into diversified portfolios – an approach commonly used by investors in several contexts, but little investigated in the context of rural electrification. This paper addresses the question of how spatial diversity in a portfolio can be used to reduce investment risks and increase investment volumes through a mixed-method approach involving three steps: (i) identification and classification of investment risks for renewable energy mini-grid projects, (ii) qualitative analysis of the correlations between investment risks for different projects through interviews, and (iii) quantitative estimation of the cost of capital and derisking effects of spatial diversification strategies for an experimental portfolio in India. We discuss the implications for policymakers in promoting and facilitating the ability of private sector investors to aggregate small-scale electrification investments.

1. Introduction

About 1.1 billion people lack access to electricity worldwide. An estimated 48 billion USD of annual investments are required to provide electricity access to them by 2030 (IEA and World Bank, 2015). Compared to the investment of 13 billion USD in 2013 (IEA, 2015), this represents a need to scale up investments significantly. Private investment is likely to play a major role in meeting this target (UNCTAD, 2014). However, how to attract these investments is an aspect that has not received sufficient attention in the literature on rural electrification. Off-grid electrification projects are often unattractive for private investors due to unfavourable risk-return profiles and small investment volumes (Schmidt, 2015). Both issues can potentially be addressed by aggregating projects into larger, diversified portfolios. The potential of aggregation to redirect financial flows into small-scale renewable energy is beginning to be recognised internationally. For instance, solar home system developers in East Africa such as BBOXX and M-Kopa have closed aggregation transactions in 2016. Internationally, the Climate Aggregation Platform (CAP) initiative was announced at the COP21 climate talks in Paris (UNDP; GEF; CBI, 2015). However, there are very few studies investigating financial aggregation of renewable energy assets in developing country or off-grid contexts.

Most existing studies analysing investment risks for renewable mini-grid projects focus on measures to reduce risks, and to increase stable revenue streams for mini-grid developers (Schmidt et al., 2013; Aggarwal et al., 2014; Schnitzer et al., 2014; Williams et al., 2015; Comello et al., 2017). These studies focus on single projects, and do not consider the role of investment risks for portfolios of such projects. Lowder and Mendelsohn (2013) and Alafita and Pearce (2014) evaluate the potential for aggregation of distributed renewable power generation, but only for grid-connected PV in the United States. The potential for aggregation of off-grid power in developing countries, a theme that is missing in these studies, is taken up by Davidsen et al. (2015), Gershenson et al. (2015) and (Orlandi et al., 2016). They discuss the benefits of structuring pooling facilities which can aggregate projects to reduce risks, increase investment volume, and lower transaction costs. All the studies evaluating the potential for aggregation discuss the benefits of spatial diversification, i.e., investing in a portfolio of projects located across different geographic distances and jurisdictions.

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However, there is a lack of studies conducting a systematic assessment of all possible risks, their respective contributions to financing cost as well as correlations between the risks (Schmidt, 2014). A better understanding of risks, correlations, and aggregation strategies can help private investors and policymakers formulate strategies to aggregate assets in order to attract private investments.

This study, focusing on the role of mini-grids in achieving decentralised rural electrification, addresses the question: *How can different project aggregation strategies be used to enable private sector investment in renewable energy mini-grids in developing countries?* It presents a first analysis of the derisking effect of portfolio diversification on decentralised renewable energy mini-grid projects in the two Indian states of Uttar Pradesh and Bihar. Specifically, it analyses how spatial diversity in a portfolio can be used to reduce investment risks and increase investment volumes. This is done through a mixed-method study involving (i) identification and classification of the major investment risks for decentralised renewable mini-grid projects based on literature and expert interviews, (ii) qualitative analysis of the correlations between perceived investment risks for mini-grid projects through structured interviews with investors, project developers and industry experts, and (iii) estimation of the derisking effects of different diversification strategies across four levels (from village to national level) for an experimental portfolio by applying modern portfolio theory in a bottom-up techno-economic model.

The remainder of this paper is structured as follows: Section 2 reviews the existing literature on aggregation and diversification of risks in investments for rural electrification. Section 3 describes the research case for this study. Section 4 describes the methods used, and Section 5 presents the main findings of the study. The implications for policymakers, limitations for the current analysis, and avenues for further research are discussed in Section 6.

2. Literature review

This section provides a review of investment needs and barriers for mini-grid based rural electrification projects (Section 2.1). It provides an overview of concepts related to risk diversification, and of studies applying them to investments in the power sector in general and rural electrification in particular (Section 2.2).

2.1. Investment needs and barriers for mini-grid based rural electrification

With the launch of the Sustainable Energy for All (SE4All) initiative in 2011, the UN General Assembly's declaration of the decade 2014–2024 as the Decade of Sustainable Energy for All, and the announcement of the Sustainable Development Goals (SDGs), achieving universal access to modern energy services by 2030 has become a major goal for sustainable development. Given the unprecedented scale of this undertaking, several studies have estimated the level of investments required to achieve this goal. Bazilian et al. (2010) estimate annual costs till 2030 ranging from 12 to 134 billion USD, with the wide range largely owing to variation in underlying assumptions such as the level of electrification, technologies employed, and fuel costs. The IEA (2011), on the other hand, provides a point estimate of 48 billion USD annual investment. In a more recent report, they note that actual investments in 2013 only amounted to 13 billion USD, which is projected to increase over time, averaging 30 billion USD annually between 2015 and 2030 (IEA, 2015).[1] Despite the large variation in estimates, it is commonly acknowledged that the private sector investments will play an indispensable role in meeting global targets (IEA, 2011; Bhattacharyya, 2013a; UNCTAD, 2014; Pueyo et al., 2015).

However, rural electrification projects in developing countries, especially off-grid projects based on renewable power, are often unattractive for private investors. These projects typically have unfavourable risk-return profiles and small investment volumes (Schmidt et al., 2013; Schmidt, 2015; Williams et al., 2015). Further, renewable based projects, owing to their high up-front cost, are influenced to a much larger extent by higher financing costs as compared to fossil fuel-based generation (Schmidt, 2014). Consequently, there has been considerable attention towards identifying, classifying and understanding risks and measures to address them.

Several studies have discussed investment risks for mini-grid projects, applying different classification criteria. For example, Williams et al. (2015) review and classify barriers to private sector investment into three interdependent categories – financial, institutional and policy, and technical barriers. Similarly, Hazelton et al. (2014) identify technical, organizational, social, sustainability, financial, and safety risks for solar PV hybrid mini-grids. Franz et al. (2014) organise risks at the macro level into political, social, economic, and financing risks. Ahlborg and Hammar (2014) identify investment barriers in Tanzania and Mozambique, which they classify into the categories 'weak institutions and barriers', 'economy and finance', 'social dimensions', 'technical system and local management', 'technology diffusion and adaptation', and 'rural infrastructure'. Schmidt et al. (2013) distinguish between risks arising from barriers at the local, national and international level. Waissbein et al. (2013) classify investment risks by associating them with a specific stakeholder whose actions have the potential to result in negative impact on the project finances, and quantify their impact on cost of financing for renewables. They also propose policy and financial derisking instruments, i.e. public derisking instruments aimed at mitigating investment risks and transferring them to a public institution, respectively. Thus the existing literature provides a good qualitative understanding of different investment risks and barriers for mini-grid projects. However, these studies generally focus either on single projects, or on barriers in the investment environment, without analysing how they might affect a portfolio of projects. Further, none of them indicate the relative importance of different risks in terms of impact on financing costs for a diversified portfolio.

2.2. Diversification of risk

Modern portfolio theory (MPT), first introduced by Markowitz (1952), provides a framework to quantify the risk reduction associated with diversification of assets in an investment portfolio. According to MPT, the expected return of a portfolio is the weighted average of the expected returns of the individual assets. The portfolio risk, defined as the variance of returns of the portfolio, depends on the variance of the returns of each of the assets, and on the correlations between the assets' returns. Mathematically it can be represented as:

$$V(R) = \sum_{i=1}^{n} x_i^2 \sigma_i^2 + \sum_{i}^{n} \sum_{j \neq i}^{n} x_i x_j \sigma_i \sigma_j \rho_{ij}, \quad (1)$$

where $V(R)$ is the variance of the expected returns of the portfolio, x_i is the fraction of the total portfolio investment amount invested in asset i, σ_i is the standard deviation of the returns of asset i, and ρ_{ij} is the correlation coefficient between the returns of assets i and j. When the returns of individual assets in a portfolio do not perfectly correlate (i.e. $\rho_{ij} < 1$), the variance of the returns of the portfolio is lower than that of the individual assets.

Investment risks can be broadly classified as unique risks and market risks (see Fig. 1). According to MPT, within one market, only unique (or project-specific) risks, are not perfectly correlated and may be addressed by diversification (Brealey et al., 2012). In order to reduce

[1] Regional estimates further highlight the disparity in estimates of investment needs. See, for example, 2.4–3 billion USD for India estimated by Banerjee et al. (2015); 922 million to 12.7 billion USD for India estimated by CKinetics (2013); 7.8–78 billion estimated for two extreme scenarios in sub-Saharan Africa by Bazilian et al. (2012).