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Challenges of decentralized electrification for economic development: lessons from experience

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Abstract

This paper uses a meta-analysis to investigate the challenges of decentralized electrification for economic development. It uses an original database which has evaluation data on more than 400 projects. Technological innovations, notably for solar energy, are opening new space for electrification policy, based on off-grid systems, which are particularly relevant for remote rural areas. However there are two main challenges. Firstly due to the threshold effects associated with the size of the projects based on nano size systems, typically the popular Solar Home Systems (SHS). Nano systems do not reliably lead to the transformation effects which are necessary to ensure economic sustainability. This may lead to a poverty trap. Secondly the bigger the system, the bigger the need to organize collective action for planning, installation, and management. This collective action requires proper governance structures, which can be designed using Ostrom's framework for the management of common pools of resources.

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1. Introduction

The consequences of access to electricity on development have been a relatively minor topic in development economics, except for some valuable contributions to the impact evaluation literature (e.g. Chaplin *et al*, 2017; Dinkelman, 2011; Khandker *et al*, 2012; Peters *et al*, 2011). There is generally little doubt that having access to electricity improves living conditions, either directly or indirectly, through its economic transformation impact. Until recently the principal issue of electrification policies was related to the quantity of supply, determined by grid extension, which was primarily constrained by financing capacities. The focus on grid extension left little room for considerations of the heterogeneity of electricity supply except for some consideration of the consequences of outages. Frequent outages in developing countries imply a high cost on businesses (Foster, 2009) as well as on households (Chakravorty *et al*, 2014). The economics of electricity access was enriched by these considerations, but it was essentially considered as a sectorial question.

We argue that development economists should no longer consider access to electricity as a mere sectorial issue, due to three main changes:

First, access to modern energy has been identified as the 7th Sustainable Development Goal (ensure access to affordable, reliable and sustainable modern energy for all), and it is recognized that the SDGs are related to each other. Access to electricity permits social integration and access to other essential services (Pereira *et al*, 2010), and may have an influence on most of the other SDGs through its effects on health, education, women's empowerment, agricultural modernization, economic transformation, security, etc.

Second, technological changes are creating growing opportunities for building new modes of electrification through off-grid solutions. These off-grid solutions (stand-alone solutions or mini-grids) provide a variety of possible accesses to electricity, with characteristics which are vastly different from the main grid. It is now recognized (SE4All, 2017) that access to electricity should be analyzed in a multi-tier framework, defined principally by categories of power size and intermittence of the system. Whether electricity is accessed through off-grid solutions or through connection to the national grid has vastly different implications. Off-grid solutions offer new space for development strategies in rural areas which were previously too far from the main grid to have access to electricity, or were affected by frequent outages. In addition, off-grid electrification offers a continuum of solutions - giving the possibility of gradually climbing the energy ladder, whereas on-grid electrification entails threshold effects, which are possibly responsible for individual or local poverty traps (electrification traps in the words of Peter *et al* (2011)).

Third, these new technological developments are also associated with new questions related to governance. A major issue faced by the main grid electricity sector in developing countries is the integrity of the system, with big systematic thefts of power and corruption, which are to a large extent responsible for the bad quality of the service (Berthélemy, 2016). These governance issues may be dramatically different when electricity is supplied off-grid. A mini-grid is a local public good, whose governance can be studied using the framework developed by Ostrom (1999). Berthelemy (2016) argues that the main grid deficiencies in developing countries are classical examples of the tragedy of the commons, which may be better solved by off-grid systems. Ostrom's theory on the tragedy of the commons suggests that centralized public goods (the main grid) are more difficult to govern than decentralized public goods (off-grid solutions). The governance of decentralized public goods relies on trust and interactions between the members of the local community (the commoners). So institutional questions come to the forefront of studies on electrification, and they deserve particular attention because the design principles proposed by Ostrom in the context of a common pool of natural resources require careful adaptation in the context of the production and distribution of electric power.

We argue that off-grid electrification should attract a lot more attention from development economists - it offers new development opportunities, particularly for rural development; it opens new questions on the possibilities of escape from poverty traps; and it requires new institutional thinking, which could contribute to the literature on the governance of the commons.

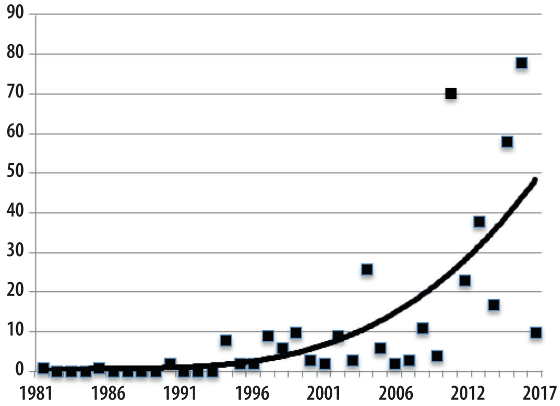
As an emerging topic, off-grid electrification has been little documented in previous development economics literature, but it is attracting a growing interest from practitioners. In order to derive lessons from this growing literature, we have built a database, which gathers information available in published evaluations of off-grid electrification projects. This database has information on the characteristics of off-grid projects, as well as on their developmental outcomes, defined using the SDG framework. It has a collaborative dimension, because we have contacted, when possible, all authors of these publications to validate our understanding of their conclusions and in some case obtain complementary information. This data base, called CoSMMA (Collaborative Smart Mapping of Mini-grid Action), is still under development, as more publications become available, but it contains enough information to draw, by a meta-analysis, preliminary conclusions about the challenges and outcomes of off-grid electrification.

In section 2, we provide a brief description of CoSMMA. In section 3, we present the main findings of our meta-analysis about how off-grid project characteristics determine the probability of obtaining positive developmental impact. In sections 4 and 5, we discuss further research avenues for development economics which are opened by the study of off-grid electrification: section 4 is focused on techno-economical aspects and the discussion of poverty traps, and section 5 is devoted to institutional aspects and the question of governance of local public goods. Section 6 concludes.

2. The CoSMMA database

The research papers used to document decentralized electrification projects (DEPs) for CoSMMA were taken from 4 economic research academic databases: Academic Search Premier, Business Source Complete, EconLit, and GreenFILE. Papers with a publication date after 1980 were selected. This date was chosen to avoid missing any important precursor publications about decentralized electrification. However, because the interest in decentralized electrification is recent, papers before 1990 are scarce (see Figure 1).

Figure 1. Number of projects by publication year



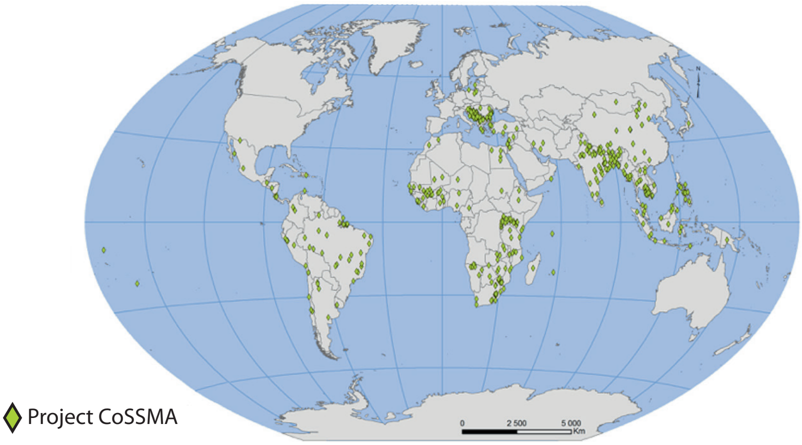
A key sentence containing words defining DEPs was used and parsed through EBSCO for the 4 databases. Keywords were automatically reweighted by a smart text mining function in EBSCO. Some variants were also used. The keyword-based sampling approach gives a random selection of papers related to the DEP effectiveness field of research. However, the ability of an algorithm to fit accurately to a field of research cannot be guaranteed, and so *ex-post* human checks were performed on the EBSCO selection results. Some articles with large bibliographies were used to define sub-branches, in which some of the papers quoted in the bibliography of the head article were collected as well. However, the bibliographies of initial articles were used with parsimony, because too many papers from sub-branches could have introduced a bias toward the past into the meta-analysis, and also a direction bias: at a given point in time, a researcher can only cite previously published papers, and papers closely related to his or her own research direction.

For reasons related to this research project's history, 32 articles were also used, following a classic approach based on literature search about the econometric evaluation of decentralized electrification. These articles did not duplicate those from EBSCO. They constitute an extra section of the database. The additional papers (from sub-branch or history) are 18% of all the collected papers. After this selection process, the dataset for statistical analysis contains 403 evaluated projects, with a total of 2,712 effects.

Additional information about CoSMMA can be found in Berthelemy and Millien (2018).

Figure 2 presents the geographical distribution of the DEPs in the CoSMMA, and demonstrates that CoSMMA is based on a wide geographical spread of experiences.

Figure 2. Map of DEPs in CoSMMA



The evaluation approaches implemented in the papers used in CoSMMA are very diverse, from scientific impact assessment to descriptive observations. A major issue in the literature on DEP effects is that the vast majority of paper report effects, but do not attempt to prove them statistically. The evaluations reported in such papers represent low quality information compared to evidence-based evaluations. As usual, in the standard meta-analysis literature, we focus on evidence-based (scientific) evaluations in our econometric analysis.

The unit of measurement chosen to describe the structure of our dataset corresponds to measured effects, because this is also the focus of our econometric analysis. We identify 3 kinds of evaluation: scientific evaluation, quantified but not tested (descriptive)(?) evaluation, and expert evaluation (i.e. qualitative assessment based on expert opinions).

The most frequently reported effects correspond to SDG 7, on access to modern energy, but many evaluations consider effects related to other SDGs, particularly Poverty eradication (SDG 1), Health (SDG 3), Education (SDG 4), Gender (SDG 5), and Economic transformation (SDG 8). Some tested effects correspond also to societal and environmental improvements: Community (SDG 11), Environment (SDG 13) and Security (SDG 16). Finally, some observed effects are not particularly related to SDGs but may be nevertheless meaningful, such as effects on time availability or access to information and communication.

As shown in Table 1 scientific attempts to test the impact of DEPs have a focus on education, health, and to a smaller extent energy access. By contrast descriptive and expert data evaluations have a focus on energy access, economic transformation, and environment.

Table 1. Distribution of evaluation data by type of effect

Type of effect | Mode of evaluation	Scientific	Descriptive	Expert
SDG related effects (SDG No.)			
Education (4)	205	65	79
Health (3)	174	47	92
Electricity access (7)	136	339	508
Economic transformation (8)	32	80	132
Income & living conditions (1)	30	25	36
Gender (5)	24	15	42
Security (16)	21	28	7
Community (11)	1	20	61
Environment (13)	0	42	180
Other effects			
Usable time & leisure	51	11	20
Information & communication	38	25	28
Housework	34	5	10
Financial transformation	6	25	27
Migration	0	6	5
Total	**752**	**733**	**1,227**

As regards project characteristics, our focus on scientific data gives a distorted picture of the reality of off-grid electrification projects, on two dimensions: energy source and system size. Economists who have attempted to test with scientific data the impacts of off-grid electrification have focused on projects based on systems powered by photovoltaic panels. These systems are mostly SHS (solar home systems), solar lanterns and solar street lamps. They have been the focus of research because they rely on new, easy to install, affordable technology. In CoSMMA there is more information on alternative solutions, which are a minority of installed systems, and an even smaller minority of scientifically evaluated DEPs. This is shown in Table 2:

The DEPs which use solar solutions are evaluated with scientific data in 43% of cases, while only 5% of evaluations of non-solar DEPs are scientific. In CoSMMA there are many off-grid energy solutions which have been implemented but not evaluated with scientific methods, such as hybrid renewables, biomass, geothermal, and wind. As a consequence, we can reach conclusions on best practices only for DEPs based on solar, fuel, hybrid solar/fuel, and hydropower systems, and the findings on non-solar solutions are hardly conclusive given the dearth of scientific evaluations for such solutions.

Table 2. Distribution of evaluation data by DEP Energy Source

Energy source | Mode of evaluation	**Scientific**	**Descriptive**	**Expert**
Solar	698	457	451
Fossil fuels	22	36	34
Hydropower	16	46	148
Hybrid – Solar/Fossil fuel (??)	15	73	71
Existing energy mix, incl. Fossil	1	16	44
Hybrid renewables	0	45	114
Biomass (and related tech.)	0	34	167
Existing energy mix, Renewables only	0	26	6
Geothermal & Tidal	0	0	104
Wind	0	0	88
Total	**752**	**733**	**1,227**

As regards the power size of systems, our sample of data with scientific evaluations is biased towards the evaluation of nano-systems (less than 1 kW), as opposed to micro-grids or mini-grids (see Table 3). 55% of evaluations of nano solutions are based on scientific data, whereas 95% of evaluations of micro or mini-grids are based on descriptive data or expert opinions. This is a major shortcoming in the existing evaluation literature (Eales *et al*, 2018). We expect that nano solutions generate relatively few impacts, restricted to the use of appliances that can be plugged into the system (principally electric bulbs and recharge devices for cell phone batteries).

Table 3. Distribution of evaluation data by DEP system size

System Power | Mode of evaluation	Scientific	Descriptive	Expert
Nano: <1 kW	729	309	288
Micro: 1 to 100 kW	13	281	621
Mini: 100 kW to 100 MW	10	143	316
Unidentified	0	0	2
Total	**752**	**733**	**1,227**

With respect to the governance of projects, the evaluation papers provide little information, because governance issues have so far rarely been considered in this literature. We usually know the decision level, which leads to a discussion of the relative merits of top-down and bottom-up approaches. On this matter, the characteristics of our sub-sample of scientific data are not too distant from the rest of DEPs evaluations registered in CoSMMA, as shown by Table 4, which presents the structure of evaluated projects by decision level, from country level to local level. Both top-down and bottom-up approaches have been applied to DEPs, and submitted to scientific evaluation. We have also been able to obtain from published papers, or from contacts with authors, information on the existence of the clear and public role of project stakeholders. In this respect our sub-sample of scientific data is comparable to the full sample.

Table 4. Distribution of evaluation data by DEP decision level

Decision level| Mode of evaluation	Scientific	Descriptive	Expert
Country & Multi-country	120	423	688
Province	344	46	200
County	138	3	5
Local & District	150	261	334
Total	**752**	**733**	**1,227**
Clear and public role of project stakeholders			
No	226	137	404
Yes	526	596	823

3. Which DEP characteristics lead to proven favorable effects: a Meta-analysis

In our sub-sample of scientific data, we are able to separate proven and unproven effects. The direction of an evaluated effect is considered as proven if it is statistically significant at the standard 5% level (at less than 5% it is probably mistaken to conclude that the measured effect is proven), positive in the case of an observed favorable effect, or negative in the case of an unfavorable effect. A striking feature that emerges from the data collected in CoSMMA is that only a minority of conclusions are actually based on significant parameters. We have only 208 proven favorable effects versus 262 unproven favorable effects, and only 71 proven unfavorable effects versus 191 unproven unfavorable effects. There are 20 effects reported as inconclusive. We are mainly interested in identifying the determinants of proven favorable effects, so as to characterize best practice. To do so we estimate a multinomial probit, which takes into account the five possible outcomes.

Although our interest is focused on the proven favorable outcome, estimating the full set of parameters associated with all 5 outcomes in a multi-probit regression provides a way to enrich our estimation, because estimating the determinant of other outcomes indirectly provides information about the DEP characteristics which limit their ability to have positive impacts (proven favorable effects). Parameters are obtained from a maximum likelihood estimation of the following equation:

$$P(\text{outcome}_{ip} = k) = \text{constant} + c.\text{EvalCond}_{ip} + s.\text{ProjectSpec}_{p} + \text{error-term}_{ip}$$

Where:
– p is a project
– i is an observed or reported effect
– outcome = k is one of 5 possible outcomes
– EvalCond_{ip} is a vector of control variables of an evaluation's conditions
– ProjectSpec_{p} is a vector of a project's specifications
– Error terms are clustered by projects

The results are reported In Table 5. We comment principally on the first column of parameters, which are marginal effects associated with the determinants of the probability of observing a significant favorable marginal effect.

We control for the type of effect, as not all evaluated effects have the same probability of occurrence. We find that two types of effect are more significantly favorable than others: Access to energy and Information and communication. Access to modern energy being the primary objective and outcome of electrification, its favorable occurrence is naturally more probable than other effects, which usually require complementary actions, assets, or inputs. This was shown, for instance, by Kudo *et al* (2019) who assessed the impact of a program of lantern distribution to school children in Bangladesh and found that its positive consequences on educational performances depended on the quality of teaching provided by the school system. The similar marginal effect observed for Information and communication is related to the fact that access to electricity facilitates recharging of cell phones, by far the most popular and already widely disseminated electrical appliance: 60% of Africans possess a cell phone, which is much higher than the proportion of Africans who have access to electricity at home.

We also control for a number of other conditions of evaluation (not shown in Table 5): number of observations used to test impacts on DEPs (not significant), econometric methodology (evaluations using an identification strategy are possibly more precise and lead to more proven favorable effect estimations), delay of evaluation (not significant), independence of the investigators (not significant), and continental location of projects (not significant).

We test the merits of the different technologies. Solar technology is by far more conducive to proven favorable effects than hydropower and systems powered by fuel. Hybrid (solar/fuel) systems have also on average a high probability of producing proven favorable effects, but given the small number of related observations the corresponding parameter is not precisely estimated.

We obtain clear results concerning the effect of system size. Nano systems lead less frequently to proven favorable effects than micro- and mini-grids. Nano systems have also a higher risk of leading to proven unfavorable effects than micro- or mini-grids. The negative average marginal effect associated with nano systems is a lot bigger than the average marginal effect associated with solar technology. This implies that the most popular DEPs, based on SHS, do not perform particularly well. A micro- or mini-grid will outperform nano solar systems, whatever its source of energy. The best performing solution appears to be hybrid solar/fuel systems, which usually power micro-grids. The combination of the two sources of energy provides more power, and hybrid systems solve the issue of the intermittence of solar energy.

Next, we test the role of governance of DEPs by comparing the outcome of DEPs initiated at different decision levels, from the closest to the beneficiaries (local level) to the furthest (national level). Locally decided projects might take population needs better into account. They might also be based on a governance structure attentive to promoting cooperation in resource management, thereby preventing the emergence of free-riding issues. These arguments are in favor of bottom-up approaches in which community engagement from the early stages plays a key role. On the other hand, projects decided at country level, could benefit from a higher degree of expertise, experience, and from positive scale effects. These two opposing arguments suggest that both bottom-up approaches and top-down approaches can lead to positive impacts, which may lead to a U-shaped relationships between the level of decision and the probability of obtaining positive impacts. We observe such a U-shaped relationship in Table 5.

We also observe that top-down approaches are more risky than bottom-up approaches because they lead more frequently to proven unfavorable effects.

Table 5. Effectiveness characteristics of DEPs - Average Marginal Effects

Explanatory factors	(1) proven favorable	(2) unproven favorable	(3) proven unfavorable	(4) unproven unfavorable	(5) inconclusive
Type of effect (ref. = Energy access)					
Income & living conditions	-0.442***	0.124	0.275	0.049	-0.006**
Health	-0.449***	0.315***	-0.026	0.078	0.082***
Education	-0.371***	0.188***	0.066	0.123	-0.006**
Gender	-0.427***	0.279*	-0.053	0.171	0.030
Energy access	0.000	0.000	0.000	0.000	0.000
Economic transformation	-0.493***	0.043	0.073	0.384**	-0.006**
Community	-0.596***	0.804***	-0.045	-0.156**	-0.006**
Security	-0.383**	0.219***	0.013	0.074	0.077**
Financial transformation	-0.455***	0.267***	0.228***	-0.034	-0.006***
Housework	-0.370*	0.100	0.190	0.058	0.022
Information & communication	0.006	0.061**	-0.052	-0.021	0.006**
Usable time & leisure	-0.423***	0.194	0.071	0.150	0.009
Technology (ref. = Hydro)					
Hydropower source	0.000	0.000	0.000	0.000	0.000
Solar	0.282***	0.318***	0.125***	-0.746***	0.021***
Hybrid – Solar/Fossil fuel	0.203	0.344***	0.038*	-0.673***	0.088
Fossil Fuels	-0.005	0.969***	-0.003***	-0.974***	0.013
Nano size	-1.244**	-0.261	0.564***	0.979**	-0.039
Programme Decision Level (ref. = Local)					
Country	0.060	-0.101	0.167***	-0.029	-0.097
Province	-0.360*	0.224***	0.070**	0.183***	-0.116
County	-0.409***	-0.024	-0.076***	0.653***	-0.145
Local	0.000	0.000	0.000	0.000	0.000
Stakeholders inclusion,	0.958***	-0.850***	0.606***	-0.930***	0.216***
Total N in Mprobit	**751**	**751**	**751**	**751**	**751**
Obs. Number of outcome	**208**	**261**	**71**	**191**	**20**

Control variables for delay of estimation, number of observations in estimation, independence of investigators, method of inference, and continental location not shown
***, **, and * = statistically significant at 1%, 5%, and 10%

Whatever the decision level, the results may be influenced by the intrinsic quality of the governance structure at the relevant decision level. A key factor is the clear and public role given to stakeholders. Although the inclusion of stakeholders does not necessarily guarantee the success of DEPs, their exclusion is probably a serious obstacle. We find, as expected, that inclusion of stakeholders in the governance structure has a very large positive marginal effect on significant favorable outcomes of DEPs, but this effect is countered by a significant risk of proven unfavorable effects.

4. Threshold effects in off-grid electrification and the poverty trap hypothesis

Our investigation of the factors which give positive impacts of DEPs provides a first approach to the conditions in which such projects are successful. The absence of observed positive impacts would suggest that the project is going to fail. There are many reported failures, which have led researchers to examine the conditions of sustainability of DEPs. We discuss in this section how the technical design of DEPs may affect their sustainability. As explained earlier our database is not big enough to discuss the choice of energy sources, which in any case will depend on local resources. We are however able to discuss the choice of the size of the systems that are installed.

Specifically, if the positive impact of DEPs depends on their size, there may be negative threshold effects to the sustainability of DEPs based on nano systems. Nano size systems may face difficulties to have positive impacts on socio-economic development if their sustainability is negatively affected by the fact that they do not generate enough income to cover their costs (Roche and Blanchard, 2018).

This leads us to discuss the productive nature of impacts that can be obtained with nano systems. Productive impacts are associated with the kind of appliances that can be plugged into the system, and many productive appliances, such as electrical tools or water pumps may require more power than can be supplied by a nano system. This will create a threshold effect, in which a too small investment in capacity leads to lack of payback and so to failure due to economic unsustainability. Conversely mini-grids may lead to economic transformation, which provides resources to cover their costs, as shown for example by Kirubi *et al* (2009) in a case study in Kenya.

Similar phenomena have been subject to many discussions in development economics in the context of the debate on the possible existence of poverty traps. Kraay and McKenzie (2014) argued that the frequent observation of very small investments by entrepreneurs implied the absence of threshold effects. In the case of electrification investment new decentralized nano solutions seem to follow this argument, except if nano system prove to be unsustainable due to lack of enough positive impacts on incomes and/or due to the unwillingness of the customers of the system to pay.

Testing econometrically the dependence of the nature of impacts on the size of the system is not possible with our current data due to the relatively small amount of scientific data on micro- and mini-grids. In order to obtain enough descriptive data on the nature of the impact of nano systems versus micro- or mini-grids we extend our initial sample with descriptive and expert data. First, we define a successful project, for a given type of impact, as a project with proven favorable effects and without proven unfavorable effects. We extend this definition to descriptive and expert data by assuming that two descriptive/expert favorable (unfavorable) effects are equivalent to a proven favorable (unfavorable) effect. We then count the number of projects deemed successful for each category of impact. We present in Table 6 the results obtained for 4 broad categories of impact: Energy access, Income poverty reduction (which encompasses income & living conditions, Economic transformation and Financial transformation), other impacts on individual wellbeing (Education, Health, Gender, Homework, Usable time & leisure and Information & communication), and Social well-being (community, security, environment and migration).

We expect that poverty reduction increases the capacity to pay for the costs of the system, while wellbeing improvements may increase the willingness to pay. The striking result in Table 6 is that nano systems relatively rarely reduce poverty, compared to micro- or mini-grids. This observation suggests that DEPs based on nano systems may fail in the long run due to lack of the transformation effects needed to generate additional income to sustain the recurrent costs of the system.

Table 6 reports also more positive social well-being effects for nano systems than for micro- or mini-grids, which corresponds principally to effects on security (street lighting), but the number of observations on social well-being impacts is small so that this result should not be over-interpreted

Table 6. Proportion of successful projects by size and type of effect

	Nano systems		Micro- and mini-grids	
Type of effect	**% of successful projects**	**Number of projects**	**% of successful projects**	**Number of projects**
Energy access	59%	29	71%	48
Poverty reduction	63%	16	100%	16
Individual well-being	67%	18	83%	30
Social well-being	67%	9	45%	11

5. The governance of off-grid electrification: contribution to the literature on the commons

Our discussion on the effects of system size implies that micro- and mini-grids may be better than nano systems such as SHS. This brings to the fore the questions related to collective action and local governance. Our observations on the institutional determinants of positive outcomes of DEPs can be interpreted in the context of Ostrom's analysis of the common pool of resources (Gollwitzer *et al*, 2018). The role of the local governance structure, and the inclusion of stakeholders are key elements which contribute to the design principles identified by Ostrom (1999) for the governance of a common pool of resources. They are necessary to guarantee the congruence between appropriation and provision rules and local conditions. They also facilitate collective-choice arrangements and monitoring (accountable to the commoners).

Another key element of Ostrom's design principle is the recognition of the right to organize granted to the commoners, which must be set at the national level. In addition, by application of the principle of subsidiarity, some rules, for example on technical standards or the enforcement of competition, are best designed at the national level. This implies that a proper set of regulations, partly specific to off-grid electrification, should be put in place. National authorities in charge of the electricity sector regulation increasingly recognize this, but not all of them have yet put such specific regulations in place.

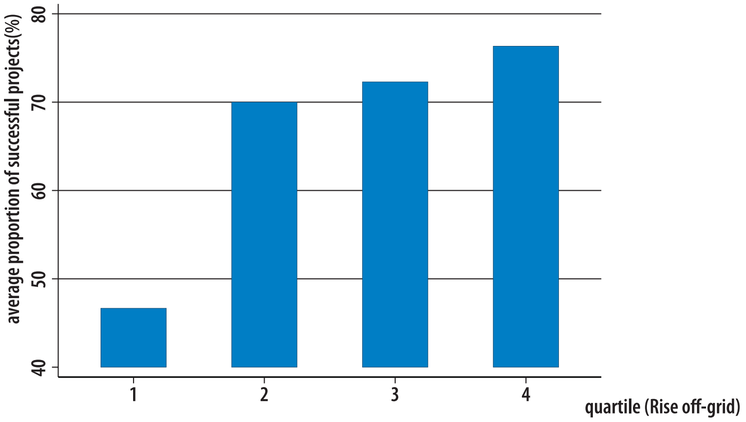
The Sustainable Energy for All initiative (SE4All) gathered information available on the institutional frameworks of energy access policies in a database called RISE (for Regulatory Indicators for Sustainable Energy). The latest available synthesis by ESMAP (2018) confirms the important role played by regulatory and incentive policies. We complement CoSMMA with this data to explore these questions for off-grid electrification.

For off-grid electrification, the RISE data base collects 5 criteria: existence of a national program, existence of a legal framework, possibility of translating costs into tariffs, financial incentives, and technical standards. The average of these 5 criteria provides an indicator of the quality of the institutional framework in the decentralized electrification sector.

Unfortunately, there is still much missing data in RISE concerning this indicator. The number of countries present in our extended sample (defined earlier) is limited (37 countries), and the intersection of the two data sets is only 20 countries. In addition, we have no more than 3 evaluated projects in a majority of countries. Hence individual country information is hardly interpretable. Therefore these data are at best illustrative.

We present in Figure 3 the average proportion of projects, by quartile, of the RISE off-grid indicator. It suggests, as expected, that countries with a lower quality of institutional framework for off-grid electricity also have a lower proportion of successful projects. This is particularly true for the first quartile.

Figure 3. Off-grid institutional framework and proportion of successful DEPs.



6. Conclusion

Our investigation of data collected in the CoSMMA database provides useful information on the challenges of off-grid electrification and identifies possible approaches to solve them. In spite of the relative scarcity of scientific evidence-based impact assessments for DEPs, we are able to derive from the existing data clear conclusions on two aspects: the necessity to build relatively large systems, typically micro- or mini-grids rather than nano systems (such asSHS), and the necessity to build governance systems that organize efficiently the corresponding collective action required to build micro or mini-grids.

The question of the size of the systems is an important one in a context where the vast majority of implemented projects are based on nano-sized systems (less than 1 kW). Our econometric analysis shows that nano systems lead much less frequently to proven favorable effects than micro- or mini-grids. This result is complemented by descriptive data, which suggest that nano size projects lead much less often to successful transformation effects than bigger systems. Hence a poverty trap could occur, in which relatively small investments are more likely to emerge but are also more likely to fail.

Building bigger projects requires collective action, so the success of DEPs depends on their governance. The conceptual framework developed by Ostrom to analyze common pools of resources provides a useful starting point. The three decision levels involved in the governance of local public goods, stakeholders, local community, and national authorities are equally important. The inclusion of stakeholders is essential to secure their cooperation and prevent free riding. The local community governance structure must be mobilized from the beginning to ensure the congruence of the project with local needs and ensure that practices are implemented to meet such needs. National regulations must also be enforced to ensure that legal and technical standards are met.

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