World Development 140 (2021) 105347

Contents lists available at ScienceDirect

World Development

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

Leveraging private investment to expand renewable power generation: Evidence on financial additionality and productivity gains from Uganda

Benedict Probst [a,*], Lotte Westermann [b], Laura Díaz Anadón [a], Andreas Kontoleon [a]

[a] Cambridge Centre for the Environment, Energy and Natural Resource Governance C-EENRG, Department of Land Economy, University of Cambridge, United Kingdom
[b] Evaluation Department, German Development Bank KfW, Germany

ARTICLE INFO

Article history:

Keywords:
Renewable energy
Feed-in-tariff
Developing countries
Climate policy
Economic productivity
Financial additionality

ABSTRACT

Effectively mitigating climate change entails a quick upscaling and redirection of electricity infrastructure investment towards clean power. Given that the bulk of greenhouse gas emissions increases until 2050 will come from low- and middle-income countries, finding cost-effective ways to mitigate climate change while meeting development targets is essential. However, recent research has shown some of the limitations of broad financing mechanisms, such as the Clean Development Mechanism (CDM) and existing carbon markets. This has resulted in a growing interest in designing novel investment support schemes, such as modifications of feed-in tariffs (FiTs) that may be more cost effective and better targeted towards particular outcomes when compared to traditional deployment subsidies or broad financing mechanisms. We evaluate the design and outcomes of one such novel support schemes: the GET FiT (Global Energy Transfer Feed-in Tariff) investment support scheme in Uganda, which has attracted ~ 453 million USD in private sector investment for 17 small-scale renewable energy projects (solar, hydro, bagasse) in only three years. Using financial modelling on detailed project-level data, we find that most projects were additional and would therefore not have been built without the subsidy. In addition, using firm-level panel data, we show that power outages hamper manufacturing performance in Uganda. In the absence of reliable outage-data for the entire Ugandan territory, we use nightlight variations to proxy changes in outages. We show that outages have declined substantially since the introduction of GET FiT. Yet, our analysis also demonstrates that programmes to incentivise additional renewable generation in developing countries funded internationally or domestically should liaise closely with grid authorities to ensure that supply does not outstrip demand.

1. Introduction

For many countries in Sub-Saharan Africa (SSA) unreliable and insufficient power supply poses a substantial challenge to poverty alleviation and economic development. In the region, 57% of the population – around 600 million people – do not have access to electricity and continuous power outages hamper the economic performance of those already connected to the grid (IEA, 2018). As in many other countries in SSA, the dual challenges of providing access to electricity and keeping power supply stable for those connected to the grid is severe in Uganda (Blimpo & Cosgrove-Davies, 2019). In addition, as the bulk of greenhouse gas emissions increases until 2050 will come from low- and middle-income countries (Dechezleprêtre, Glachant, Johnstone, Ménière, & Haščič, 2011), finding cost-effective ways to mitigate climate change while meeting development targets is essential. While SSA features high solar irradiation and wind speeds in many regions, fossil-fuel based power generation still accounts for a substantial fraction of total power generation, which emits local land global pollutants.

Providing access to clean, affordable, and reliable electricity in the region requires significant increases in power sector investment, particularly given substantial economic and population growth (Huenteler, 2014). Using 2005 as a baseline, the World Bank (2011) estimated that Sub-Saharan Africa needed to add at least 8 GW between 2005 and 2015 of generation capacity to meet its growing power demand and electrification targets in line with poverty reduction goals. Yet, the average over the last decade has been 1–2 GW (Eberhard, Gratwick, Morella, & Antmann, 2017). This additional capacity in power generation in excess of the historical trend in SSA was estimated to require financing of roughly US$ 40 billion p.a., which is equivalent to 38% of the combined

* Corresponding author.
E-mail addresses: bsp26@cam.ac.uk (B. Probst), Lotte.Westermann@kfw.de (L. Westermann), lda24@cam.ac.uk (L.D. Anadón), ak219@cam.ac.uk (A. Kontoleon).

https://doi.org/10.1016/j.worlddev.2020.105347
0305-750X/

annual government tax returns of all countries in Sub-Saharan Africa (Eberhard et al., 2017; World Bank, 2018). The large magnitude of the investment needed, combined with the strained financial situation of the governments in many of those countries, necessitates a big role for private and/or international finance.

Existing studies underscore that private investments in the power sector will not materialise without a suitable investment environment, which involves adequate financial returns, a transparent regulatory environment and other political, socio-economic and financial factors (Waissbein, Glemarec, Bayrakta, & Schmid, 2013; Probst, Holcroft et al., 2020; Probst, Anatolitis, Kontoleon, & Díaz Anadón, 2020). While there are several studies investigating the factors driving renewable power investment from the private sector (Bürer & Wüstenhagen, 2009; Surana & Anadon, 2015; Probst, Holcroft et al., 2020; Probst, Anatolitis et al., 2020), there is a paucity of studies investigating the effectiveness of public instruments to crowd in private capital into renewable power in developing countries (Polzin, Egli, Steffen, & Schmidt, 2019).[1] In a review of existing studies, Lindenberg (2014; p.33) concludes that "[a] quantitative assessment of the effectiveness and efficiency of public spending that is aimed at mobilising private funds for green investments in developing countries has not yet been carried out for the simple reason that data is not available."

We therefore contribute to filling this gap in the literature by investigating the design and local economic impacts of one of the first schemes in developing countries aimed at crowding in private capital for the construction and operation of renewable power generation assets: The Global Energy Transfer Feed-in Tariffs (GET FiT). In 2013 the GET FiT programme was launched with about 104 million USD of development funding from the German Development Bank KfW and other donors. Within three years, it attracted ~453 million USD in private sector investment for 17 medium-sized renewable electricity projects. To our knowledge, the comprehensiveness and transparency of financial data that we received from the GET FiT programme administration is unmatched in any other evaluation of a similar type of programme.

Our two central research questions therefore are: First, how has this novel financing approach – which in contrast to existing schemes tackles both the risk and return of private investors – performed in crowding in investment from the private sector (i.e., financial additionality); and how does it on average compare to other approaches including pure return-approaches, exemplified by the Clean Development Mechanism (CDM), and pure risk-mitigation approaches addressing political risk such as the Multilateral Investment Guarantee Agency (MIGA)? As studies on MIGA are scarce, we will primarily focus on the return-improving programmes, such as the CDM, where there is a substantial literature. Another reason why we focus on risk-return approach is that existing studies from industrialised countries show that tackling both risk and return concurrently is more effective than merely addressing one or the other; yet studies on that for developing countries are scarce (Polzin et al., 2019). Within the first research question, we also investigate whether reductions in risk primarily translate into lower cost for debt and/or equity for renewable energy project developers.

Second, have the GET FiT funded medium-sized renewable energy (5–20 MW) plants, distributed geographically across the country, contributed to improved economic development outcomes through the provision of more reliable electricity by the reduction in power outages for private households and/or firms? If so, what is the economic effect in terms of firm productivity through this channel? Understanding the effect of renewable power generation on firm performance is important, as arguments in favour of renewable generation are commonly advanced on purely cost and environmental grounds. Yet, second-order effects, such as increased firm performance due to greater grid stability, are not commonly investigated.

We rely on two methods to study these research questions. First, applying financial modelling on detailed project-level data, as well as insights from more than 60 interviews with developers, investors and government agencies, we estimate the financial additionality of the programme and the evolution of financing risks. We analyse financial additionality by modelling the financial returns of all GET FiT funded projects – hence, both rejected and accepted by the programme – and then using those that were rejected, but went ahead even without support, as a counterfactual (see Section 4 for more detailed explanation). Second, in order to study the local economic effects and the influence of outages on firm productivity, we use detailed manufacturing and nightlight data to study whether the new power plants are reducing outages.

Using financial modelling on detailed project-level data, we find that the majority of projects that received a subsidy from the GET FiT programme were additional and would therefore not have been built without the subsidy. In addition, using firm-level panel data, we show that power outages hamper manufacturing performance in Uganda. In the absence of reliable outage-data for the entire Ugandan territory, we use nightlight variations to proxy changes in outages. We show that outages have declined substantially since the introduction of GET FiT. Yet, our analysis also demonstrates that programmes to incentivise additional renewable generation in developing countries funded internationally or domestically should liaise closely with grid authorities to ensure that supply does not outstrip demand.

The remainder of the paper is structured as follows: Section 2 describes the policy context in Sub-Saharan Africa and Uganda, and outlines different approaches for catalysing private sector investment in renewable power in developing and emerging economies. In Section 3 we discuss the GET FiT programme. In Section 4 we then move on to discuss our data sources and methodology, whereas Section 5 details the results of our analyses regarding financial additionality and possible productivity gains associated with the GET FiT programme. Section 6 presents our conclusion and policy recommendations.

2. Overview of different approaches to incentivise private sector involvement

In order to gauge whether a project is financially viable, investors rely on several metrics. These include the Net Present Value (NPV) of projects, which is the discounted difference between the cost and the revenues generated by a (power) project. The NPV of a project needs to be positive for an investor to go ahead. Another metric is the so-called Internal Rate of Return (IRR), which is the rate of return on capital at which the NPV becomes zero. It is then compared to the discount rate, or so-called hurdle rate, to determine whether an investment is desirable. Generally, the higher the IRR and NPV the more attractive an investment is (UNFCCC, 2011). As these metrics can be used across investments of different types, they are good measures for inter-project comparison. However, there are risks that investors may not be able to correctly quantify or to manage (including financing, technology, integration, and country/political risks and off-taker risk), making the projects only feasible at very high financing cost,

[1] Van de Sijpe et al. (2019) propose a probabilistic approach to assess whether development finance institutions' (DFI) investments are more or less likely to be additional. As other studies, however, they assess the additionality of DFI investments and not of private sector investors that are nudged to invest by DFI interventions such as the GET FiT approach to improve the risk-return profile of renewable energy investments.

increasing the overall cost of the project and hence of the electricity delivered (Kreibiehl & Miltner, 2013).

Policies that aim to increase the participation of private actors in the power sector can generally use two levers. First, programmes can increase investors' return from the project (Fig. 1): These can include price premiums on existing feed-in tariffs, tax breaks or the sale of carbon credits (e.g., through certified emissions abatement). Second, programmes can attempt to lower the risk of developing and operating renewable power projects. These include financial risks and policy risks. Financial risks can be mitigated, for instance, via power purchase agreements, in which a private or state-controlled utility agrees to purchase power for a set number of years (e.g., 20) for a specific price. Instead of relying on the wholesale market, which reflects the balance of demand and supply, developers outsource all price risk to the utility purchasing the power. Policy risks are those related to the regulatory environment. These include the risk that there may be retroactive changes to the feed-in tariff by the government, which may be perceived as too high.

A significant risk factor in many countries is so-called offtaker risk. This is particularly true in many SSA countries, such as Kenya (Pueyo, 2018) and Uganda (Meyer, Eberhard, & Gratwick, 2018), among others. Uganda Electricity Transmission Company Limited (UETCL) is also perceived to be a risky financial offtaker. Therefore, the Ugandan government has issued sovereign guarantees to power project developers since 2012 (Meyer et al., 2018). Even if the government provides guarantees, delayed payments are a major risk for renewable energy developers, for which other short-term liquidity supporting approaches can be used (Probst, Holcroft et al., 2020).

Given substantial economic and political differences between high and low/middle-income countries, policies that have induced renewable power development cannot merely be 'transplanted' from industrialised countries. While the evidence from the industrialised economies is instructive in devising policy toolkits, there are many additional challenges in low- and middle-income countries (Polzin et al., 2019). These include lower institutional capacities, corruption, lower budgets and political instability. Yet, low-income countries may benefit from two decades of research and renewable power buildout, which has decreased the cost through R&D, learning by doing, economies of scale, and learning in financing (Egli, Steffen, & Schmidt, 2018; Qiu & Anadon, 2012).

How to best support developing and emerging economies in their transition to clean energy has been the focus of substantial debate in academic and policy circles (Huenteler, 2014). This is particularly relevant as there has still been little agreement on the specific design of Article 6 of the Paris Agreement, which allows countries to coordinate climate change mitigation and adaptation measures internationally. It will likely contain a market mechanism to promote the ambitious aims of the Paris Agreement and avoid many of the pitfalls inherent in the Kyoto Protocol's Clean Development Mechanism (CDM). Yet, as the specific design of Article 6 has been the source of major contention, it was postponed at the COP24 and COP25, and will be negotiated at the COP26.

Table 1 provides an overview of the name, technology, start, policy levers and the geographic scope of various schemes that intend to accelerate private sector investment in clean technologies in developing countries. We divide the approaches to the extent that they address two crucial decision metrics of investors in line with Polzin *et al.*, (2019): investment risk and investment return (or a combination thereof). Risk is understood as "[..] the effect of an unpredictable event on the project value, considering both the probability of possible events and their financial impact in the case that they materialise" (Polzin *et al.*, (2019; p.2). With increasing risk, a higher market premium on top of the a risk free rate is expected, which is commonly calculated as the yields of a US treasury bond with 30 day maturity (Grabowski, Nunes, & Harrington, 2014). Table 1 it not exhaustive and is meant to provide an overview of the different policy levers that are used to target investors' return and/or risk.

The GET FiT approach can be classified as a combined risk-return approach, since it tackles both return (through paying the incremental cost of utilities between the maximum purchase price and the price determined administratively (FiT) or through auctions) and sources of financial and policy risk (e.g., through capacity building). The Clean Development Mechanism (CDM), in turn, can be seen as a return-increasing mechanism and specifically focuses on improving the return of investors through the direct sale of carbon credits generated through the process. However, its main focus was not addressing sources of financial and policy risk. In contrast, the Multilateral Investment Guarantee Agency (MIGA) primarily safeguards investors against political and non-commercial risk in developing countries and can therefore be seen as a risk-mitigation approach (MIGA, 2019).

2.1. Measuring financial and emissions additionality

Irrespective of the type of approach to incentivise private-sector investment, one critical question is whether it leads to additional renewable power infrastructure investment. Development agencies and governments want to understand whether their funding actually leads to projects that would not have happened without the funding. If the funding was not necessary for the buildout, policy makers would have merely increased the profit of renewable energy developers (often at the expense of tax payers). While these additional revenues may be re-invested into other projects, existing incentives would have been already sufficient for the project.

In the climate change domain, typically two types of additionality are distinguished (Chan, 2015). First, financial additionality, which refers to the question whether the project would have been financially feasible without the funding.[2] Financial additionality is a necessary but not sufficient condition for the second type: emissions additionality. This refers to the question whether the new power plant actually substitutes more emissions-intensive sources of power. It could be, for instance, that a new solar PV plant, that would not have been built without the financial incentive, but merely substitutes power from another clean-power source, such as small hydro projects. It therefore would be financially additional but not emissions additional.

The largest programme in the domain of incentivising the buildout of renewable power generation in developing countries is the Clean Development Mechanism (CDM) (Schneider, 2009). The CDM administration used an additionality investment tool, generally considered a robust approach if performed well and data is credible. The investment analysis is performed to gauge whether the investment would have been financially viable without the additional funding which the project receives through the sale of carbon credits. However, a major point of concern for this analysis is that the benchmarks used to establish additionality are often unreliable and outdated. For instance, in China an 8% IRR benchmark was used for CDM projects that was taken from a 2002 report from the State Power Corporation of China ("Interim Rules on Economic Assessment of Electrical Engineering Retrofit Projects")

[2] A range of multilateral development banks have further refined the definition of financial additionality, by explicitly specifying different types of financial additionality. These refer to 1) financing structure (e.g., financing not available in the market from commercial source), 2) innovative financing structures and/or instruments (i) lowering cost of capital or by addressing risk, ii) not available in local markets at reasonable cost), 3) MDB's Own Account Equity (Equity that cannot be assessed through the market) and 4) resource mobilisation (mobilisation of capital from private sources) (MDB, 2018).

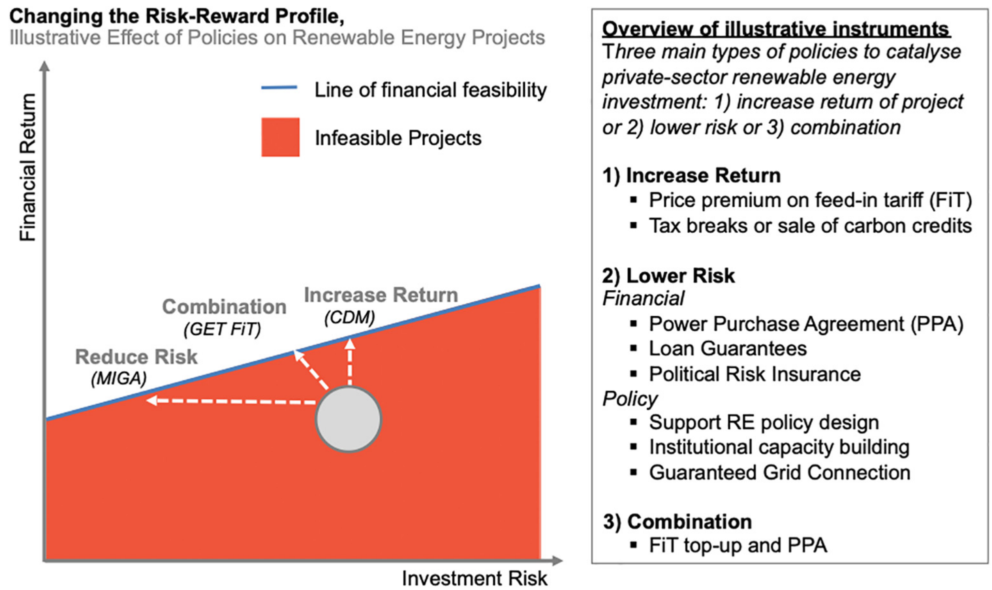

Fig. 1. Effect of different policies on risk-reward profile of different renewable energy projects. Infeasible projects are those where the financial return is not sufficient to justify the investment risk (i.e., risk of losing the investment) based on Polzin et al. (2019) and Waissbein et al. (2013). MIGA refers to Multilateral Investment Guarantee Agency, CDM to Clean Development Mechanism and GET FiT to the Global Energy Transfer Feed-in Tariff.

Table 1
Overview of different funding schemes to incentivise private-sector investments in green technologies based on author. *Note: MIGA is the Multilateral Investment Guarantee Agency (MIGA), which safeguards investors against political and non-commercial risk in developing countries (MIGA, 2019). provides Its projects cover a wide range, so listing is merely indicative of approach. All mechanisms are still ongoing. GET FiT and Scaling solar are combined risk-return approaches, using both risk and return levers to make investment in renewable energy in developing countries more enticing. In contrast, MIGA primarily focuses on mitigating risk, whereas the CDM focuses on increasing return. The list is not exhaustive but is meant to provide an indicatory overview of different approaches.

Type	Name	Technology	Start	Policy Levers					Geographic Scope
				Return			Risk		
				Price-mechanism (FIT)	Quantity-mechanism (auctions)	Direct (sale carbon credits)	Financial	Policy	
Combined Risk Return Approach	GET FiT	Small Hydro, Biomass	2013	x			x	x	Uganda
	GET FiT	Solar	2013		x		x	x	Uganda, Zambia
	Scaling Solar	Solar	2015		x		x	x	Ethiopia, Madagascar, Senegal, Zambia
Risk Mitigation Approach	Multilateral Invesment Guarantee Agency (MIGA)*	All foreign direct investment	1988				x	x	Developing countries
Return Increasing Approach	Clean Development Mechanism	All low-carbon technologies	2007			x			Non-Annex I Parties

The dependent variable is log sales in real 2005 UGX. Labour is the log number of employees, capital is the log machinery value of each firm, outages are the hours of outages per month for a given firm. Generator is the number of hours the generator runs per month, and the interaction between the two continuous variables outages and generator is how both variables are jointly related to the dependent variable log sales.

(Chan, 2015). This IRR was used to guide the unbundling of the vertically integrated utility, but had no empirical justification. Apart from providing no credible IRR, using a constant IRR as benchmark ignores changing market conditions, such as lower policy risk due to a more capable regulator.

In the largest review of the CDM by the Öko Institut, SEI and Infra for the DG Climate of the European Commission the authors draw the following conclusion: “Overall, our results suggest that 85% of the projects covered in this analysis and 73% of the potential 2013–2020 Certified Emissions Reduction (CER) supply have a low likelihood that emission reductions are additional and are not over-estimated. Only 2% of the projects and 7% of potential CER supply have a high likelihood of ensuring that emission reductions are additional and are not over-estimated (Cames, 2016, p.11)." These results are corroborated by other empirical research, who find that in the case of China wind projects supported through the CDM were not any less viable than those outside of the programme. These led to emissions reductions certificates equivalent to the amount of three years of emissions reductions in the European Union Trading Scheme, which were no additional emissions reductions (Chan and Huenteler, 2015).

Generally, the shortcomings of the CDM to establish credible additionality in many domains, has led several researchers to suggest that approaches such as the CDM should ideally be used only in niche areas, where it is evident that no business case exists for the abatement of certain greenhouse gases (Cames, 2016). For instance, landfill gas flaring has a high likelihood of providing additional emissions abatement opportunities as there is no current business case for doing so otherwise. In contrast, efficient lighting projects have a low likelihood of being additional, as the transition away from incandescent lightbulbs is occurring even in the absence of additional funding through the CDM (Cames, 2016). Yet, if the investment analysis draws on accurate data and vetted, time-varying IRR baselines, IRR analysis can give a credible indication of additionality and is used in this study.

2.2. Measuring the economic impact of reduced outages

As highlighted in the introduction, the installed power generation capacity for most African countries cannot keep up with economic and population growth. Lacking investment in maintaining the existing grid further complicates this issue. Insufficient generation capacity and lack of investment in the existing grid leads to both the quantity and quality of power to be inadequate. In terms of quantity, the World Bank (2011) estimated that SSA needed to add at least 8 GW between 2005 and 2015 of generation capacity to meet its growing power demand and electrification targets in line with poverty reduction goals. Yet, the average over the last decade has been 1–2 GW (Eberhard et al., 2017). Similarly, Ugandan firms – and many other countries across the continent – see unreliable electricity as one of the major impediments to firm productivity. Hence, it is clear that outages are a significant impediment to economic and firm productivity, yet to measure and quantify the effects is challenging.

The main empirical challenge in understanding the impact of outages on economic development is that outage data is not commonly available. In many developing countries outages are often monitored by manual record, which is susceptible to recording errors. Even if digital monitoring systems are in place, these records are generally not publicly available, given the sensitivity of the data. In Uganda for instance no outage data is available and the same holds true for many other developing and emerging economies.

Given the dearth of outage data, researchers have used variation in nightlight – captured through satellites passing over a region at a certain time at night – is that it assumes that a greater variability of nightlights indicates more outages. This is because places with few outages will exhibit more stable nightlights, whereas places with high variability likely experience higher variation.

Several studies have been conducted relying on nightlight data to study the impact of outages on economic productivity and firm choices. For instance, Alam (2013) uses nightlight variation in India to study whether firms change their production processes to cope with outages. She finds that depending on the coping strategy, an increase in the frequency of power outages reduces the output and profit of only a part of the electricity-intensive industry.

As outage data is commonly not available for many developing countries, many studies rely on nightlight images from the National Oceanic and Atmospheric Administration (NOAA) This approach was pioneered by Alam (2013) to gauge the performance impact of outages on steel manufacturing plants in Indian districts. However, to our knowledge, there are not studies that have used this data to study the effect of renewable power generation on outages, specifically in Africa.

3. The GET FiT programme

In 2007, the Ugandan government launched its Renewable Energy Policy, in which it set a target of 1420 MW (which includes large hydro) by 2017 (Meyer et al., 2018). This target represented a more than doubling of existing renewable and thermal generation capacity. In order to spur investment in clean power through independent power producers (IPPs), it introduced a feed-in tariff (FiT) in 2007. However, the FiT attracted limited interest from project developers as it was relatively low given the risk profile of the country. Despite the low attractiveness of the FiT, Uganda still attracted several IPPs during that time, which entered into direct negotiation with the government (total 28 MW in small-scale hydro power).

However, in 2012 it became clear that Uganda needed to increase the speed and scale of investment in its power generation infrastructure. It was expected that the country would run into power supply constraints between 2015 and 2016. The country would then need to rely on emergency heavy-fuel oil generators, costing roughly twice as much as the average power generation cost in Uganda. The GET FiT programme was therefore launched in 2013 to fast-track the deployment of 157 MW of small renewable power projects throughout four main application rounds in three technologies (small hydro, bagasse and solar) with installed capacity between 5 and 20 MW.[3] As the FiT had attracted limited investment, the programme was expected to accelerate the deployment of renewable power generation projects. It has since become evident that the power supply gap was not as acute as initially believed due to lower power demand growth between 2013 and 2018 (Meyer et al., 2018). As two major hydropower plants are expected to come online in 2019–2020, this may put the Ugandan utility purchasing the power into financial difficulties. As the domestic demand may not be sufficient to absorb these increases in power generation capacity, the utility may suffer from the obligation to purchase the power while being unable to fully sell the purchased power.

The programme was jointly developed by the Government of Uganda, the Ugandan Electricity Regulatory Authority (ERA) and the German Development Bank (KfW) and is supported by a number of other donors, such as the Governments of Norway, Germany, UK and the European Union. The GET FiT approach aimed to attract private sector investment in renewable energy in developing and emerging economies through the improvement of the existing regulatory frameworks and, more importantly, through paying the gap between the maximum price the utility is able to pay and the price of renewable power. The price of renewable power in the GET FiT framework is either determined through competitive auctions (e.g., solar) or administratively set through feed-in tariffs depending primarily on the type of technology used type (e.g., solar is commonly auctioned, whereas power from small-hydro is supported via FiT).

[3] We exclude the solar auction from our analysis, given that the approach to allocate funding was a reverse-auction and not a fixed top-up. In addition, we only have limited information on the applicants.

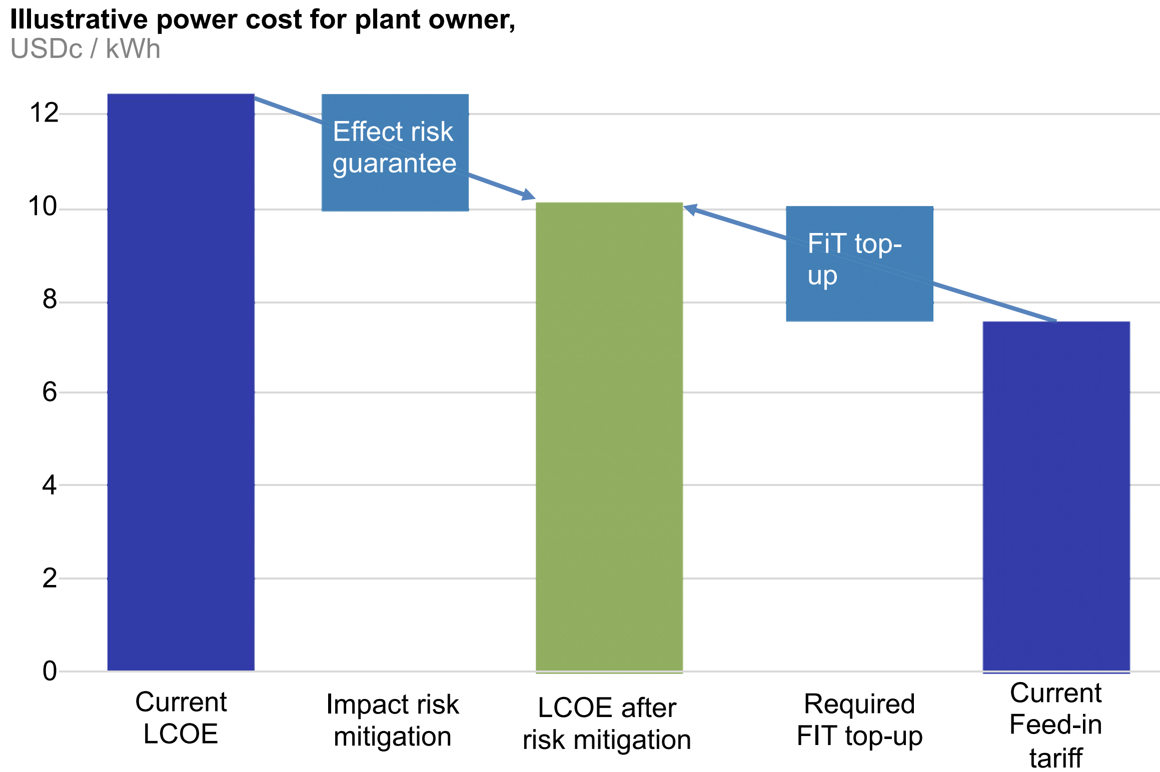

Fig. 2. Illustration of the GET FiT approach using data from the beginning of the GET FiT project in Uganda based on Kreibiehl and Miltner (2013). LCOE refers to levelised cost of electricity (LCOE), which is the average net present generation cost of a unit of electricity computed over the entire lifetime of the plant.

Table 2
Overview of GET FiT return and risk levers distinguished by programme component based on GET FiT (2018).

Overview of GET FiT revenue and risk levers		
Programme component	Lever	Details
GET FiT Premium*	Return	GET FiT projects reveive 50% of the feed-in tariff top-up at the beginning of operations, and the remaining 50% during first five years of operation
Legal Document Standardisation (PPA, Implementation Agreement, Developer Financing Agreement)	Risk	Law firm supported the relevant authorities in crafting bankable documents, which are critical in receiving funding from banks and other investors.
World Bank Partial Risk Guarante Facility	Risk	The World Bank earmarked USD 160 million for Partial Risk Guarantees, including: - Short-term liquidity for power offtaker UETCL - Investor compensation in case of early termination of PPA - Provision of commercial debt to power developers
Regulator Capacity Building	Risk	Capacity Building with local regulator ERA. Components included power tariff modelling, due diligence for power plant licenses and grid interconnection and wheeling.
Interconnection	Risk	Additional funds to bolster existing and build new grid infrastructure to ascertain power delivery from GET FiT plants.

*Note: This does not include the solar tenders, which were awarded through a competitive auction. Here the GET FiT programme pays the incremental cost between the maximum price the utility can pay and the awarded solar power tariff.

The GET FiT approach is illustrated in Fig. 2. Consider a firm that can offer power at around 12 USDc/kWh given the risk-return profile of a specific country (expressed as the levelised cost of electricity, which measures lifetime cost divided by total power generation). Yet, if current feed-in tariff is substantially below that (e.g., ~8 c/kWh), it would not allow the firm to recover its cost. Hence, two levers can be used: First, financial and policy guarantees can be put in place to reduce the risk in the market. Second, the current FiT can be 'topped-up' to increase the revenue that a firm can make. For instance, in 2012 Uganda had a feed-in tariff of around 9 USDc/kWh, which attracted little interest from project developers given that it was too low given regulatory, off-taker and broader political risks (Meier, Vagliasindi, & Imran, 2014).

The specific levers that the GET FiT programme uses are further detailed in Table 2. First, it is important to note that renewable power projects incur most of their cost at the beginning of the project. As the project cash flow improves once the power plant goes into operation, the first years can be very critical, particularly if projects are delayed. Hence, the GET FiT programme disburses the entire FiT top-up 50% at start the start of operations and 50% over the first five years of operation. While this increases the risk of the programme management in case that power projects do not deliver on their promise of operating for at least the envisaged 20 years, it reduces the risk for private developers. More precisely, project developers received an additional 1–2 USDc/kWh on the existing 9 USDc/kWh feed-in tariff, thereby increasing project returns. This adds around 20% additional revenues, which is far beyond the revenues a developer could historically achieve through selling CDM credits (Chan, 2015). In addition, CDM credits were subject to volatility and political interference (Cames, 2016).

Second, the GET FiT programme reduced the risk through a standardised power purchase agreement, which gave project developers 'bankable' documents. This means that these were transparent and thorough enough that lenders could be certain that the power generated would be purchased by the local utility – or otherwise compensated by the Ugandan government.[4] In addition, the environmental and generation permit process for power plants was shortened, further reducing risks associated with delays.

In addition, it was initially envisaged by those designing the GET FiT programme that firms would take out Partial Risk Guarantees (PRG) from the World Bank. These guarantees cover revenue shortfalls in case the Ugandan utility UETCL, the off-taker of the electricity, faces liquidity constraints. However, due to the prolonged process of getting PRGs and high associated cost, private firms avoided these guarantees. The interconnection component is critical, since lacking grid connection may force the off-taker to buy electricity that it is unable to receive (which means revenue losses, which will eventually trigger the default).

The GET FiT programme attracted the interest of both existing local companies within the country (e.g., Hydromax) and international companies with limited prior experience in Uganda (e.g., Frontier), advertised through conferences, their website and industry networks. Between 2013 and 2015, 17 projects out of 39 applications in Uganda received a top-up from the GET FiT programme. The projects are distributed geographically throughout the country, which provides a major change to the reliance on few big hydropower plants (see Supplementary Information). Projects were ranked on their financial, environmental/social and technical performance by the programme administration.

4. Data and methods

The following section provides an overview of the methods (4.1) and data sources used in our study (4.2).

4.1. Data

We received detailed financial data from KfW German Development Bank, which structured the programme with the Government of Uganda and strongly supports the programme's management. Applicants who seek to be supported by the GET FiT programme need to hand in extensive documentation regarding the financial, technical and environmental performance of the proposed projects.

These project documents are standardised (for instance, all projects needed to hand it the same audited financial data) and are therefore comparable across applications. In addition, each project proposal was further scrutinised by an independent consulting firm, which vetted the validity of the input assumptions for both technical and financial parameters through field visits, hydrological assessments and detailed financial models. To the best of our knowledge, the type, quality, and completeness of the information available on the cost, performance, and financing of each applicant to the program has not been available for other programs. For example, for many Clean Development Mechanism (CDM) projects, the financial information was commonly relatively sparse, unstandardized and hard to verify (Chan, 2015; Haya & Parekh, 2011; Michaelowa, 2011; Schneider, 2009).

We also rely on more than 60 interviews conducted between 2015 and 2018 with donors, government officials and IPPs to verify our assumptions underpinning the estimation strategy, analyse local capacity building and collect primary data not reflected in the data provided by KfW. We provide more information on the types of organisations, interviews and protocol in the Supplementary information.

Data on the impact of power outages on manufacturing sales is from the World Bank Enterprise Survey, which collects a representative firm sample of the formal sector for 139 countries in the world (World Bank, 2019). This data is widely used across different studies. Nevertheless, this data has – to our knowledge – not been used specifically to study the connection between outages and firm productivity in Uganda (World Bank, 2013). Our sample contains 431[5] manufacturing firms from 2006 and 2013. The data was collected using stratified random sampling using information on firm sector, firm size, and geographic region (World Bank, 2013).[6] We only include firms in the manufacturing sector, as these are the primary power consumers of the country.

As outage data is commonly not available for many developing countries, we use nightlight images from the National Oceanic and Atmospheric Administration (NOAA) to create our own outage indicator. To that end, we compiled a dataset with changes in nightlight activity analysing more than 100 nightlight images and creating indicators for each of the lowest administrative units of Uganda. This approach was pioneered by Alam (2013) to gauge the performance impact of outages on steel manufacturing plants in Indian districts. However, to our knowledge, this is the first time this is used to measure outages in Africa and to study the effect of renewable power generation on outages. As detailed data on the industrial structure of Uganda is not available, we do not weigh the outage data by location-specific industry density. However, most of the industrial output in Uganda comes from major cities in the Uganda (e.g., its capital Kampala and Jinja) (Shinyekwa, Kiiza, & Hisali, 2016), for which we provide detailed nightlight measures over time.

4.2. Research questions & methods

We investigate the impact of the programme in two distinct domains: financial additionality and productivity gains. First, we study the additionality of the programme by investigating whether the feed-in tariff top-up in Uganda is associated with additional power plants that would not have been built without the feed-in tariff top-up (i.e., financially additional). Second, we investigate the impacts of outages on firm productivity. Next, we examine whether lower outages can be attributed to the power plants and what the effects of more reliable power supply are on firm productivity. Fig. 3 provides an overview of the distinct research questions, data, and methods.

4.2.1. Financial additionality

An ideal methodological set-up for our first question would have used a regression discontinuity design to study whether the top-up resulted in additional power plants that were built. Private firms needed to apply for the project subsidy and were ranked on environmental, economic and social criteria. Only projects that achieved a composite score of 70 out of 100 received the top-up[7]. Given that firms were not able to manipulate the cut-off, being just over or under the cut-off is a matter of luck – i.e., random. This design feature has been used in different contexts, such as education,

[4] In addition, the presence of major donors such as KfW and DFID funding the programme, may have further reduced the risk for developers through developing standardised power purchase agreements, license procedures and other formal processes with the Ugandan regulator Energy Regulatory Authority (ERA). In addition to the guarantees, the above-mentioned FiT top-up is offered that adds around 2 USDc/kWh on the existing 9 USDc/kWh FiT.

[5] Our sample size is lower than the actual number in the Enterprise survey data due to missing values. We show in the Supplementary Information that firms are missing at random and not systematically.

[6] More detailed information on the survey can be found in World Bank (2013)

[7] For the solar auctions this was slightly different, because firms were needed to pass through a two-stage selection process: first on various environmental, social and technical criteria, and (those that remained) subsequently on price.

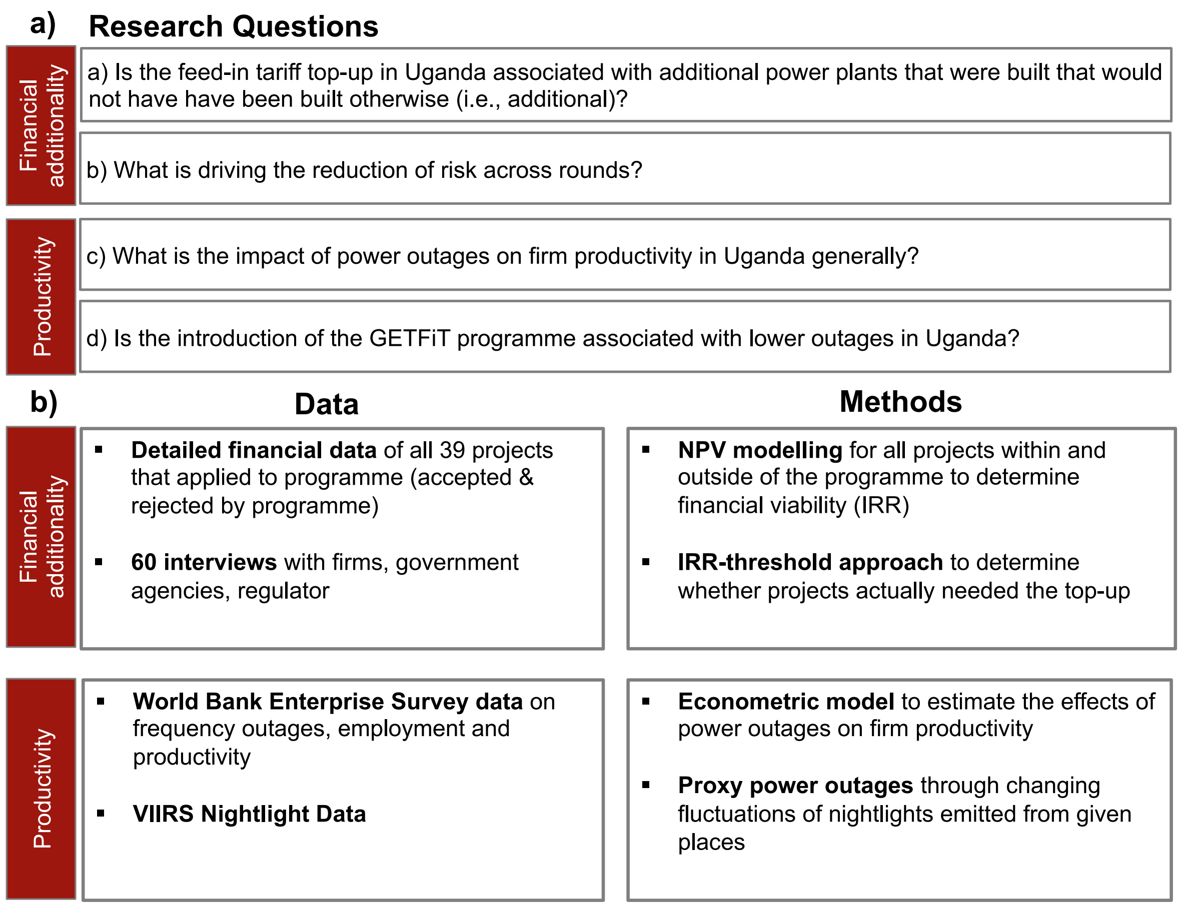

Fig. 3. a) Overview of the research questions, b) and the data and methods of our study based on author.

to study the causal effect of a given policy (e.g., scholarships effect on later academic performance; see Imbens and Lemieux (2008)).

However, given that the variability around the cut-off is not sufficient to implement a regression discontinuity design, we improve the existing CDM investment additionality approach to gauge additionality in the GET FiT programme. Firms that were rejected by the programme could still go ahead with the project. Given that at the point of application firms needed to hand in extensive financial and technical documentation, firms had already invested substantially in the project, and therefore had an incentive to go ahead with the project without applying for a new generation license.[8] We use the financial data of these projects that were rejected by the programme but went ahead anyway to create a counterfactual 'minimum' return that was required by project developers in order to implement the project. We then model the financial returns of projects that received support from the GET FiT programme to test whether they would have been financially viable even without the subsidy. If for instance, the financial return required by project developers went down over time due to lower risk, then a fixed subsidy likely over-subsidised projects in later rounds. We acknowledge that to implement our approach researchers need audited and transparent data, which may only be available in certain policy contexts.

We compute the IRR via the following formula:

$$0 = NPV = \sum_{n=0}^{N} \frac{CF_n}{(1 + IRR)^n} \tag{1}$$

where we set the Net Present Value (NPV) equal to zero, which is equivalent to setting the value of current and future cash flows across N years (CF) to zero. The IRR is then compared to the company's hurdle rate of cost of capital (which is commonly a weighted average of the cost of debt and equity). In theory, if the IRR is greater than that hurdle rate, the company would consider going ahead with the project. In reality, however, there are a number of other factors (e.g., organisational, other investment opportunities) that may influence the decision.

4.2.2. Impact of outages on productivity

In order to estimate the induced productivity effects – i.e., through fewer outages and more stable electricity supply[9] – we estimate the production function of the manufacturing sector in Uganda, which consumes the majority of electricity in Uganda. Various survey studies (World Bank, 2013) and econometric assessments underscore (Alam, 2013; Andersen & Dalgaard, 2013) that outages have a detrimental effect on productivity, even though specific assessment for Uganda are still lacking.

Production function are widely used in economics, with its most widespread functional form being the Cobb-Douglas Production[10] function It describes the relation of two or more inputs – primarily, labour and capital – to the eventual output (i.e., how much input is needed for a given amount of output?).

[8] For instance, firms needed to conduct environmental impact assessments as well as water flow measures of small hydro projects.

[9] We have no data on the reduced cost through better voltage control in the grid, as machines could be damaged if voltage is outside of acceptable boundaries.

[10] We tested the specification of the production function against other possible production functions, such as the translog production function. Yet, goodness of fit, among other tests, show that the Cobb Douglas function is better fit to our underlying data.

We estimate the following production function via a pooled panel and random effects panel model:

$$y_{it} = \alpha + \beta_1 l_{it} + \beta_2 k_{ti} + \beta_3 el_{ti} + \beta_4 X_{it} + \varepsilon_{it} \quad (2)$$

where i indexes the firm and t the year. Y_{it} in our first specification is log sales in million Ugandan shillings (UGX – 2005) in year t[11], l is labour (log number of full time employees), k is capital (log value of machinery in million UGX denominated to 2005) and el refers to two indicators, namely electricity outages (number of outages per day – not logged, given zero values) and how many hours per month the company uses its generator and X is a vector of covariates (geographic location and industry controls). We rely on the geographic information contained in the World Bank Enterprise Survey data (2006, 2013) for Uganda, which relies on six regions, which represent the bulk of industrial activity in Uganda: Jinja, Kampala, Lira, Mbale, Mbarara, and Wakiso.

We conduct a Hausmann test, which is commonly used to decide whether fixed or random effects are more appropriate in a panel setting (see Supplementary Information). The central differences between random and fixed effects is that they make different assumptions about the underlying correlation of unobserved variables. If unobserved variables are uncorrelated with the explanatory variables, then both fixed and random effects are consistent, but random effects is more efficient than fixed effects (i.e., has lower standard errors than fixed effects). However, if the assumptions is violated – that the explanatory variables and unobserved variables – are uncorrelated, then only fixed effects is consistent (but random effects is not). Even though the underlying assumptions is likely often wrong, the Hausmann test provides a metric to decide how far off the assumption is using the estimators and variance of both fixed and random effects regressions. The Hausmann test shows that random effects model is a better fit to our underlying data.

4.2.3. Nightlights as proxies for outages

The main empirical challenge in understanding the impact of outages on economic development is that outage data is not commonly available. In many developing countries outages are often monitored by manual record, which is susceptible to errors. Even if digital monitoring systems are in place, these records are generally not publicly available, given the sensitivity of the data.

We use the variation of nightlights in Uganda – disaggregated for the lowest administrative unit – to proxy outages:

$$O_{jt} = \frac{1}{n}\sum_{t=1}^{t} median(SD_{ijt}) \quad (3)$$

where O is the outage in sub-country j at time t (unit month). N is the number of months per year. Standard deviation is the monthly aggregated standard deviations of pixel i, for sub-country j at time t.

While we cannot directly detect outages this way (either outage or not), the assumption underlying this approach, which has been corroborated in the literature (Alam, 2013), is that it assumes that a greater variability of nightlights indicates more outages. This is because places with few outages will exhibit more stable nightlights, whereas places with high variability likely experience higher variation.

4.2.4. Interviews

Interviews were conducted using a semi-structured interview approach with donors, government officials and IPPs to verify our assumptions underpinning the estimation strategy, analyse local capacity building and collect primary data not reflected in the data provided by KfW.

5. Results

This part presents the results from our analysis. We first discuss whether the GET FiT support led to the construction of power plants that would not have been built without the GET FiT programme (Section 5.1).

We then move on to the relationship between firm productivity and outages in Uganda. We use panel data from the two latest World Bank Enterprise Survey (2006 & 2013) conducted in Uganda to estimate the impact of outages on firm productivity, using pooled OLS and random effects models (Section 5.2). Lastly, we investigate to what extent the introduction of the GET FiT programme is associated with lower outages. As Uganda lacks comprehensive outage data (apart from firm-specific World Bank survey data from 2006 and 2013), we construct our own measures (as discussed in methods of data), which disaggregated changes in nightlight variability in Uganda. While this is merely a proxy for power outages, we shed light on an important and under-investigated issue (5.2.1).

5.1. Financial additionality

Similar to the CDM, we also model the profitability of projects, namely the Net Present Value (NPV) and Internal Rate of Return (IRR). Both have become key metrics of investment profitability analysis since Fisher's (1907) landmark paper. This approach is used widely across policy analysis gauging the additionality of subsidies, including the CDM (Chan, 2015).

Firms that applied to receive GET FiT support needed to hand in extensive financial documentation, which was checked by the programme management. The quality (in terms of detail and reliability) of this documentation is above that of most other comparable programmes (Cames, 2016). In addition, instead of using the same metric of financial viability across different rounds (e.g., 11%), we use the lowest IRR in each round of projects that were rejected but then went ahead with construction despite not receiving funding by the GET FiT programme as the counterfactual.

Out of the 17 projects, 14 were small hydropower plants, so we focus only on this subset of plants. We do this for two reasons: First, there was only one bagasse project, and only few applications in this technology, which limits the 'counterfactual' group. Second, the solar PV projects were auctioned off through a reversed auction scheme. No solar PV projects were built in the absence of the GET FiT payments (that covered the difference between the maximum utility price and the auction price for the auctioned-off capacity). Hence, for solar PV projects we do not have a counterfactual, but given that prices in the reverse auction were substantially above the offered FiT in Uganda, this indicates that all of the solar PV projects were additional.

Fig. 4 shows the IRR calculations for the small hydropower projects. Our findings suggest that most small hydropower plants projects were additional (i.e., would not have been built without the GET FiT project support). It is evident from the data, that the profitability of projects required to go ahead with construction declined substantially across the different funding rounds, indicating lower investment risks. Our detailed investment data shows that the cost of capital – particularly equity – went down over time and across the different rounds. The GET FiT programme rightfully decreased the top-up over the rounds to account for a lower investment risks in Uganda. Nonetheless, our research indicates that, in retrospect, the phase out period could even have been shorter.

[11] Ideally, we would have the value of total production in each year, but unfortunately this is not available for the set of studied firms. We therefore rely on sales as a proxy for production.

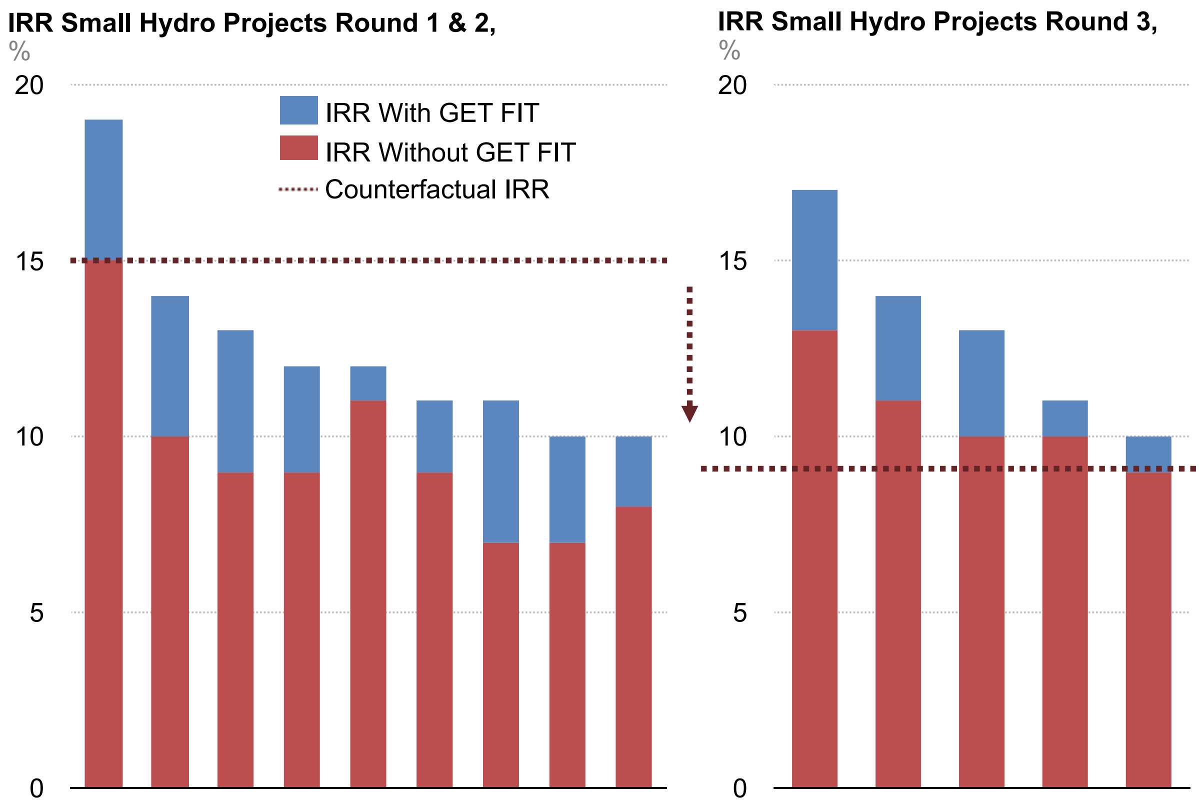

Fig. 4. Profitability of small hydropower plants in GET FiT programme with counterfactual Internal Rate of Return (IRR). The counterfactual IRR corresponds to the lowest IRR projects that were rejected but went ahead even without GET FiT support, based on KfW data. Counterfactual IRR was calculated using projects that did not get funding, but went ahead with the project even without GET FiT funding. This counterfactual data exists as firms needed to hand in detailed financial data to apply for KfW funding. In addition, these rejected firms were unlikely to change their construction design or other factors later in the process, as environmental and other permits were tied to a specific design.

It is noteworthy that many projects in round one are below the counterfactual rate even with the GET FiT top-up. This indicates that risk mitigation factors, as discussed before, were critical in lowering the risk in Uganda for firms that participated in the programme as these plants would have been unlikely to have been built without the programme. Yet, projects in the third round may have been possible even without the GET FiT top-up as the financing risk fell rapidly and substanstially between round 1/2 and 3.

However, not only a project-specific perspective should be taken when evaluating additionality: a sectoral perspective can complement the project-based one. Companies such as Hydromax, SAEMS, Tronder and Ecopower were building small run-of-the-river plants even before the GET FiT programme (Meyer et al., 2018). In the four years previous to the GET FiT programme, 28 MW of hydropower were built through these companies. However, none of them was built through the FiT but were all directly negotiated with the government, given that existing tariffs were too low. This opaque process likely limited the number of competitors and increased transaction cost for both the government and project developers. Hence, it is likely that while there might have been other small run-of-the-river projects, these would likely not have been built for the cost that the government incurred through the feed-in tariff (as the international donor community covered the additional cost).

Our analysis may even underestimate the additionality of the programme, for two reasons: First, all firms likely benefited from some aspects of the GET FiT programme, regardless whether they received funding or not. For instance, the technical training, better permits, bankable tender documents, and power purchase agreements were not only available to GET FiT participants, but also to other firms. It therefore strengthened the overall regulatory quality of the sector and mitigated policy risk. Second, some firms that got funding may have cross-subsidised unfunded projects. These additional revenues could have been used to further drive investment in the power sector in Uganda, or elsewhere in the region.

In terms of risk reductions across the rounds, we find that it primarily translated into lower equity rather than debt cost for private developers. While around 70% of debt funding came from development finance institutions, it is important to note that four out of 17 projects were financed through private sector loans. Our detailed investment data also shows that the reduction was driven primarily through lower expectations of investors on their return on equity, rather than changes in the price of debt financing or improvements in the technology (as hydropower is a mature technology).

5.2. Impact of outages on firm productivity in Uganda

After having discussed, the financial additionality of the GET FiT plants, we move on to estimations of firm productivity. Our results show that outages have a significant and negative influence on firm productivity in Uganda, reducing the sales of firms by around 0.2% (Table 3). The coefficient of outages is not significant in specification 3. This is not surprising, given that many firms might be compensating outages with generators. Indeed, in our sample around 114 out of 368 (specification 5) firms have a generator. For those that have a generator, it is responsible for 24.9% of the generated electricity. Of all the 368 firms, it supplies 8.8% of overall electricity (i.e., also including those firms that do not own a generator). Hence, firms that have a generator are able to buffer some of these sales losses through the increased use of a generator, which in turn,

Table 3
Results from pooled panel regression, correcting for heteroscedasticity and cross-sectional dependence.

Pooled Panel Regression Manufacturing (2006 & 2013)					
Dep. Variable: log sales (Real 2005 UGX)					
	(1)	(2)	(3)	(4)	(5)
Labour (log number employees)	0.817*** (0.06651)	0.852*** (0.070)	0.837*** (0.074)	0.788*** (0.077)	0.806*** (0.076)
Capital (log machinery value)	0.393*** (0.0304)	0.353*** (0.033)	0.337*** (0.035)	0.334*** (0.035)	0.337*** (0.035)
Outages (h per month)			−0.0006 (0.0005)	−0.0008* (0.0005)	−0.002*** (0.0006)
Generator (h per month)				0.001** (0.0006)	−0.00006 (0.0008)
Outage_h * Generator_h					0.000008** (0.000003)
Sub-Industry Controls	No	Yes	Yes	Yes	Yes
Geographic Controls	No	Yes	Yes	Yes	Yes
Observations	431	431	372	368	368
Adj. R2	0.663	0.6768	0.6864	0.685	0.6893

The dependent variable is log sales in real 2005 UGX. Labour is the log number of employees, capital is the log machinery value of each firm, outages are the hours of outages per month for a given firm. Generator is the number of hours the generator runs per month, and the interaction between the two continuous variables outages and generator is how both variables are jointly related to the dependent variable log sales.

Table 4
Results from random effects panel regression.

Random Effects Panel Regression Manufacturing (2006 & 2013)						
Observed in Both Periods						
Dep. Variable: log sales (Real 2005 UGX)						
	(1)	(2)	(3)	(4)	(5)	(6)
Labour (log number employees)	0.985*** (0.1233)	0.983*** (0.144)	0.971*** (0.142)	0.915*** (0.147)	0.926*** (0.1457)	0.924*** (0.124)
Capital (log machinery value)	0.313*** (0.063)	0.304*** (0.076)	0.304*** (0.075)	0.312*** (0.075)	0.310*** (0.074)	0.328*** (0.061)
Outages (h per month)			−0.0017** (0.0008)	−0.002** (0.0009)	−0.003** (0.001)	−0.003*** (0.0009)
Generator (h per month)				0.009 (0.007)	−0.006 (0.011)	−0.004 (0.009)
Outage_h * Generator_h					0.00008** (0.00005)	0.00008** (0.00003)
Sub-Industry Controls	No	Yes	Yes	Yes	Yes	No
Geographic Controls	No	Yes	Yes	Yes	Yes	No
Observations	134	134	134	134	134	134
Adj. R2	0.680	0.681	0.686	0.689	0.692	0.724

The dependent variable is log sales in real 2005 UGX. Labour is the log number of employees, capital is the log machinery value of each firm, outages are the hours of outages per month for a given firm. Generator is the number of hours the generator runs per month, and the interaction between the two continuous variables outages and generator is how both variables are jointly related to the dependent variable log sales.

also induces substantial cost to the firm. By introducing the generator variable (as a continuous variable – hours of outages per month), we are able to capture the effect of outages for those firms that do not have a generator. However, as the generator is most useful during outages, we introduce an interaction term between outages and generator, which shows that as outages increase by an additional hour, another hour of operating a generator increases sales by 0.0008%. This indicates that firms are able to buffer some of the sales losses through the generator. The coefficients of the production function for labour can capital are robust to the inclusion of new variables. While these variables are likely correlated, we check the extent of correlation in the Supplementary Information, and find – via the Variance Inflation Factor (VIF) that is still within acceptable bounds.

We also perform a panel approach to test the robustness of our results (Table 4). We check with a Hausmann-Test whether a random or a fixed-effects model is more appropriate, which indicates that a random effects model is more suitable. The model shows that sales are reduced by 0.2–0.3 % with an additional hour of outage, which is similar to the previous model (Table 4).

In terms of total cost, we estimate that the impact to businesses through an average of four hours of outages per day (in our sample) ranges between 21 and 37% of annual sales (depending on the specification used – ranging from 0.17% to 0.3% per hour of outage/month). The mean annual cost of outages per firm in Uganda range from 454,000 to 801,000 EUR and the median annual cost of outages ranges from 11,000 to 20,000 EUR (average cost is higher than median, as some firms in our sample have very high sales). For firms with generators, the cost of outages is lower, as they can buffer some of these adverse effects, but still incur additional investment, fuel and O&M cost for the generator.

5.2.1. Changes in outages in Uganda proxied through nightlights

One central question is whether outages in Uganda have been reduced since the inception of the programme. Clearly, there are other variables, such as power infrastructure investment unrelated to the GET FiT, that could confound the effect. However, in the absence of robust outage data collected by the utility, we use variations in nightlight to proxy for changes in outages on the ground. While this measure is not perfect, we are able to provide indicative evidence of outages in Uganda. As not even the national utility UETCL has reliable data on the frequency of outages, leveraging satellite imagery might be a low-cost approach to provide at least some evidence of outage frequencies in developing countries.

Overall outages seem to be decreasing in Uganda from 2014 onwards (Fig. 5). Due to lacking availability, we unfortunately have no data from before 2014. The variability in Uganda's nightlights decreased from a median standard deviation of 2.4 to 1.8 indicating more stable nightlights – and possibly lower outages. This represents a decrease in around 23% over the span of five years. Given that the average firm faces roughly four hours of outages per day, this could amount to around one hour of fewer power outages per day, if these gains were distributed equally over all firms surveyed in the World Bank Enterprise Survey. If we assume that outages decrease sales by 0.3% per hour of outage per month, decreasing outages by one hour per day (i.e., 30 per

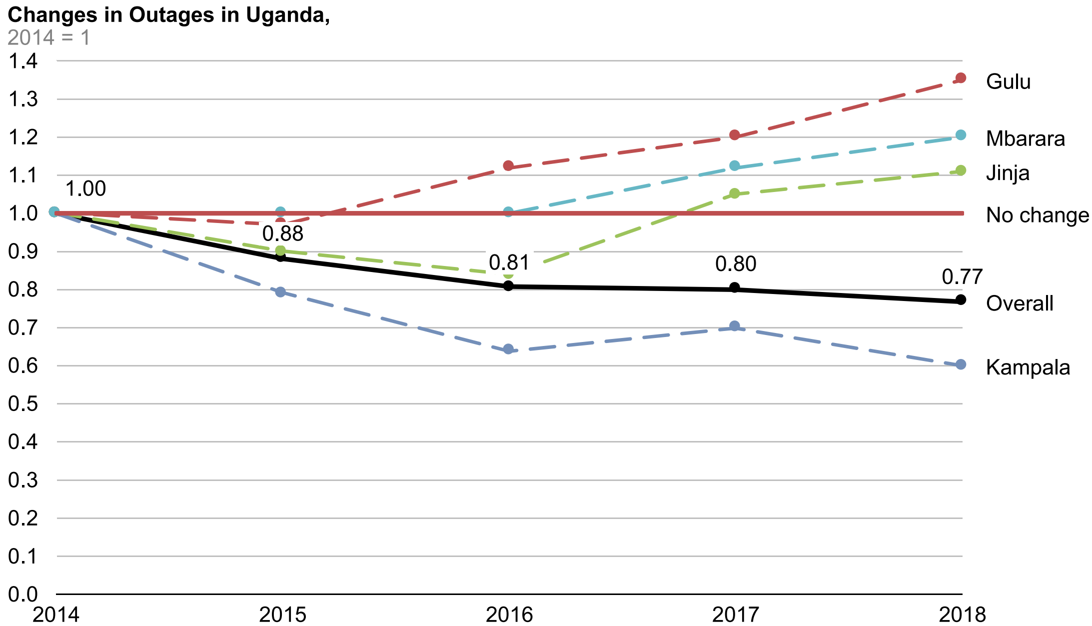

Fig. 5. Trend in median nightlight standard deviation (which we use as a proxy for outages) for the entire Ugandan territory and for the biggest city in each region based on VIIRS (2019) nightlight data.

month), this could increase firm sales per month by 9%. Yet, the geographic distribution of the reduction in outages is unequal, as this mainly happened in the Ugandan capital Kampala.

One possible explanation of these geographical differences could be that rural areas in Uganda are witnessing 'land-flight', meaning that people move to the bigger cities to seek employment and better livelihood opportunities. However, the absorptive capacities differ greatly between cities and is reliant on the quality of local institutions, housing opportunities, and family ties. It is likely that Kampala is much better at absorbing people than other cities, which have fewer financial resources. As people in the city might try to get access to electricity illegally (through fitting wires), this may further burden the already strained grid in cities such as Gulu, Jinja and Mbarara.

In addition, as Kampala hosts the parliament, supreme court and many international organisations, the political pressure is greater to provide adequate power services. It also has the best hospitals in the country, which are reliant on adequate electricity supply for their equipment and cooling of medication. While many of them have emergency generators, these are much costlier than electricity from the grid. In addition, more remote regions may have lower political leverage to put pressure on politicians in Kampala. Ethnic divisions and regional political alliances may further exacerbate this divide.

6. Conclusion

For many governments in developing and emerging economies confronting the dual challenge of increasing power generation capacity while greening the grid requires attracting private capital. Well-known limitations of existing schemes to 'crowd-in' private capital in terms of additionality, such as the Clean Development Mechanism (CDM), have increased the interest of academics and policymakers in novel financing mechanisms. Yet, both the practical experience and academic literature on this topic, particularly in Sub Saharan Africa, is scant (Lindenberg, 2014; Polzin et al., 2019). We review and classify existing financing schemes and use rich project-level data to study the design and outcomes of the GET FiT financing scheme in Uganda, which aims to jointly improve risk and return of renewable power investors. This combined risk-return approach stands in contrast to other approaches, which either seek to improve return (e.g., CDM) or financial and policy risk (e.g., MIGA) (Cames, 2016).

Our results indicate that combined risk-return renewable power support schemes such as the GET FiT programme can provide effective alternatives to established programmes in terms of financial additionality and improving investment conditions (and thereby lowering the required return on investment for investors). Our results indicate that – in contrast to what the majority of literature finds on the CDM (Cames, 2016) – that the GET FiT programme led to projects that would not have happened otherwise and hence displayed financial additionality. Our detailed project-level data indicates that the programme led to fast and tangible risk reductions in the investment risk in Uganda, attracting roughly 453 million USD in private funding for renewable power generation for 104 million USD in donor funds (leverage ratio around 1:4.5). While around 70% of debt funding came from development finance institutions, it is important to note that four out of 17 projects were financed through private sector loans. Our detailed investment data also shows that the reduction was driven primarily through lower expectations of investors on their return on equity, rather than changes in the price of debt financing or improvements in the technology (as hydropower is a mature technology). It should be noted, however, that our results are indicative and should not be interpreted as strictly causal.

Our results also show – using panel data from the World Bank Enterprise survey – outages are associated with a significant and sizeable adverse impact on manufacturing performance in Uganda, of around 0.2–0.3% reduction in sales per additional hour of outage per month. While firms attempt to offset these negative of unreliable electricity generation through generators, this can only partly offset the adverse impacts of unreliable electricity. As electricity from generators is more expensive than electricity from the grid, this increases the overall input cost of the firms.

Nightlights data indicates that outages have decreased by 23% since the introduction of the GET FiT programme. Naturally, not all of this is likely through the GET FiT programme, as the utility UETCL also invested in grid upgrades, and other factors, such as demand profiles, play an integral role in influencing outages. Yet, it is likely that an additional 20% of power generation capacity added through the GET FiT programme yielded more stable electricity supply. more stable genelectricity generation. This in turn is likely to influence firm productivity, specifically in the manufacturing sector, which consumes the majority of electricity in Uganda (Mawejje & Mawejje, 2016).

Our study does not address emissions additionality as a high-resolution power-system model would be required to adequately study emissions abatement. Similarly, we did not evaluate the cost that was saved due to the reliance on power from solar, small-hydro and bagasse instead of heavy-fuel oil generated power, which is used in Uganda in case of high demand but costs roughly twice the price that the utility pays on average for power. Another element of the programme that we did not evaluate are the impacts on biodiversity and human rights, which should be the focus of future work.

Our study also underlines that better monitoring of outages in developing countries is critical: For the GET FiT programme administration it was commonly challenging to obtain appropriate grid data, such as voltage variations and load loss at local substations. As one of the components incentivised grid-upgrades, receiving this information would have been important to monitor the overall progress of this particular component. Two approaches may yield more information in this regard. First, greater technical assistance from the international donor community. Second, leveraging satellite data and the power of artificial intelligence. Algorithms could be trained on ground-proved outage data, which is paired with satellite imagery, to better detect outages through variations in nightlight.

The GET FiT programme also offers several cautionary – yet instructive – lessons. First, proper coordination between different actors in expanding generation capacity is critical. While the GET FiT programme was introduced, the Ugandan government directly signed contracts with China's Exim bank for a large hydropower project, which will roughly double Uganda's generation capacity. This step-change in power supply with slower-than-expected growth in demand is likely to pose substantial challenges to the offtaker UETCL. The Ugandan government will then face the challenge between injecting public money into UETCL to avoid collapse or let it default on its payments, which will trigger sovereign guarantees, which have been given out to all projects since 2012.

Second, power generation investments do not automatically entail ripple-on effects into distribution, transmission or electrification. Merely focusing on expanding generation is not sufficient given that grid bottlenecks may block the transmission to demand centres, particularly if these are distributed geographically. The interconnection component of the GET FiT programme therefore was seen as critical by interviewees in ensuring the transmission and distribution of the generated electricity runs smoothly. Future programmes could attempt to partner with the electrification agency, which in Uganda is separate from UETCL, to find ways of coupling the expansion of generation capacity with local electrification. On an interesting side note: local communities who saw the construction of distribution lines, who were themselves not electrified, protested against the lack of access to power and were subsequently electrified. Hence, a more decentralised power system can also engage citizens to be more vocal about their right to access power.

Third, cost-reflective power tariffs remain an elusive goal in many developing countries, including Uganda. While tariffs have increased during the GET FiT programme, and today are more reflective of the underlying generation cost, UETCL still remains heavily reliant financial support from the Ugandan government. As renewable power is more expensive on a per kWh basis than large scale hydropower, it is unlikely that the regulatory gains that have been made will translate into more renewable generation expansion in the short- to medium term. However, once Uganda leaves the phase of oversupply (which will likely be partly mitigated through exporting power to its neighbours), these regulatory gains may translate in future renewable power buildout (perhaps as demand in neighbouring countries increases, interconnection capacity is increased, industrialising progresses more rapidly and more people are connected to the grid).

Fourth, financial additionality does not necessarily lead to emissions additionality. The heavy-fuel oil generators have been providing a substantial amount of electricity in 2017 due to increased demand from neighbouring countries. Even relatively small power systems, such as in Uganda, are interconnected with neighbouring countries. Overall, the envisaged 11 million tonnes of CO2 that the GET FiT project was expected to abate has now been corrected downwards. Counterintuitive effects in power substitution can be observed in many places, such as Europe, where the German drive towards renewable power has led to greater exports of its power produced through coal-fired power plants to neighbouring countries. Similarly, as Uganda introduced more renewable power, part of its heavy-fuel oil generators have been used to meet peak demand in neighbouring countries and hence lead to lower than expected emissions reductions.

Fifth, China is changing the importance of Western development cooperation. While Western aid is commonly tied to a number of stringent environmental, technical and social requirements, Chinese support does not come with these strings attached. For many African leaders who need to swiftly act on poverty alleviation this might be advantageous. Yet, for the environment and marginalised communities the shift towards Chines development assistance may pose challenges, as can be seen in the displacement of entire villages for the large hydropower projects in Isimba and Karuma in central Uganda. Therefore, a greater coordination with Chinese partners may be warranted.

Overall, the GET FiT programme demonstrates that combined risk-return schemes can be an effective alternative to programmes such as the CDM in terms of financial additionality and the improvement of investment conditions. In many low-income countries, merely providing price incentives without tackling the looming sources of financial and policy risk will likely not yield the expected build-out of renewable power generation. Countries particularly suited to the GET FiT approach face short-term supply constraints that can only be bridged through expensive fossil-fuel based generation (e.g., heavy fuel oil generators in Uganda). As renewable power projects, such as solar, can be developed quickly and relatively cheaply, renewable power projects can be an attractive alternative to conventional generation.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.worlddev.2020.105347.

References

Alam, M. M. (2013) 'Coping with Blackouts: Power Outages and Firm Choices', 3580619, p. 77. Available at: http://search.proquest.com/docview/1539578867?accountid=12665%0Ahttp://sfxna09.hosted.exlibrisgroup.com:3410/ntu?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:dissertation&genre=dissertations+%26+theses&sid=ProQ:ProQuest+Dissertations+%26+Theses+Gl.

Andersen, T. B., & Dalgaard, C. J. (2013). Power outages and economic growth in Africa. *Energy Economics. Elsevier B.V.*, *38*, 19–23. https://doi.org/10.1016/j.eneco.2013.02.016.

Blimpo, M. P. and Cosgrove-Davies, M. (2019) Electricity Access in Sub-Saharan Africa: Uptake, Reliability, and Complementary Factors for Economic Impact, Electricity Access in Sub-Saharan Africa: Uptake, Reliability, and Complementary Factors for Economic Impact. DOI: 10.1596/978-1-4648-1361-0.

Bürer, M. J., & Wüstenhagen, R. (2009). Which renewable energy policy is a venture capitalist's best friend? Empirical evidence from a survey of international cleantech investors. *Energy Policy, 37*(12), 4997–5006. https://doi.org/10.1016/j.enpol.2009.06.071.
Cames, M. et al. (2016) How additional is the Clean Development Mechanism? DOI: CLlMA.B.3/SERl2013/0026r.
Chan, G. (2015) Essays on Energy Technology Innovation Policy. Available at: http://nrs.harvard.edu/urn-3:HUL.InstRepos:17467190%0AThis.
Dechezleprêtre, A., Glachant, M., Johnstone, N., Ménière, Y., & Haščič, I. (2011). Invention and transfer of climate change-mitigation technologies: A global analysis. *Review of Environmental Economics and Policy, 5*(1), 109–130. https://doi.org/10.1093/reep/req023.
Eberhard, A., Gratwick, K., Morella, E., & Antmann, P. (2017). Independent Power Projects in Sub-Saharan Africa: Investment trends and policy lessons. *Energy Policy, 108*, 390–424. https://doi.org/10.1016/j.enpol.2017.05.023.
Egli, F., Steffen, B., & Schmidt, T. S. (2018). 'A dynamic analysis of financing conditions for renewable energy technologies. *Nature Energy Springer, US, 3*(12), 1084–1092. https://doi.org/10.1038/s41560-018-0277-y.
Grabowski, R., Nunes, C. and Harrington, J. (2014) 'Risk-free Rate', in Cost of Capital. Wiley, pp. 91–109. DOI: 10.1002/9781118846780.ch07.
Haya, B. and Parekh, P. (2011) 'Hydropower in the CDM: Examining additionality and criteria for sustainability', Berkeley Energy and Resources Group Working Paper, (November). Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2120862.
Huenteler, J. (2014). International support for feed-in tariffs in developing countries - A review and analysis of proposed mechanisms. *Renewable and Sustainable Energy Reviews. Elsevier, 39*, 857–873. https://doi.org/10.1016/j.rser.2014.07.124.
IEA (2018) Commentary: Population without access to electricity falls below 1 billion. Available at: https://www.iea.org/newsroom/news/2018/october/population-without-access-to-electricity-falls-below-1-billion.html.
Imbens, G. W., & Lemieux, T. (2008). Regression discontinuity designs: A guide to practice. *Journal of Econometrics, 142*(2), 615–635. https://doi.org/10.1016/j.jeconom.2007.05.001.
Kreibiehl, S., & Miltner, S. (2013). GET FiT in Uganda. *Deutsche Bank Research – Policy Paper*.
Lindenberg, N. (2014). *Public instruments to leverage private capital for green investments in developing countries*. German Development Institute.
Mawejje, J., & Mawejje, D. N. (2016). 'Electricity consumption and sectoral output in Uganda: An empirical investigation. *Journal of Economic Structures. Springer, Berlin Heidelberg, 2040*. https://doi.org/10.1186/s40008-016-0053-8.
Meier, P., Vagliasindi, M. and Imran, M. (2014) The Design and Sustainability of Renewable Energy Incentives: An Economic Analysis. DOI: 10.1596/978-1-4648-0314-7.
Meyer, R., Eberhard, A. and Gratwick, K. (2018) 'Uganda's power sector reform: There and back again?', Energy for Sustainable Development. Elsevier Inc., 43, pp. 75–89. DOI: 10.1016/j.esd.2017.11.001.
Michaelowa, A. (2011). Failures of global carbon markets and CDM?. *Climate Policy, 11*(1), 839–841. https://doi.org/10.3763/cpol.2010.0688.
Polzin, F., Egli, F., Steffen, B., & Schmidt, T. S. (2019). How do policies mobilize private finance for renewable energy?—A systematic review with an investor perspective. *Applied Energy. Elsevier, 236*, 1249–1268. https://doi.org/10.1016/j.apenergy.2018.11.098.
Probst, B., Anatolitis, V., Kontoleon, A., Díaz Anadón, L. (2020) 'The short-term costs and benefits of local content requirements: Evidence from the Indian solar auctions', pp. 1–7.
Probst, B., Holcroft, R., Huenteler, J., Balabanyan, A., Tipping, A., Robinson, P. (2020) 'Attracting Private Participation and Financing in the Power Sector in Sub-Saharan Africa: Findings from a Survey of Investors and Financiers', Policy Research Working Paper, (June).
Pueyo, A. (2018). What constrains renewable energy investment in Sub-Saharan Africa? A comparison of Kenya and Ghana. *World Development. Elsevier Ltd, 109*, 85–100. https://doi.org/10.1016/j.worlddev.2018.04.008.
Qiu, Y., & Anadon, L. D. (2012). The price of wind power in China during its expansion: Technology adoption, learning-by-doing, economies of scale, and manufacturing localization. *Energy Economics. Elsevier B.V., 34*(3), 772–785. https://doi.org/10.1016/j.eneco.2011.06.008.
Schneider, L. (2009). Assessing the additionality of CDM projects: Practical experiences and lessons learned. *Climate Policy, 9*(3), 242–254. https://doi.org/10.3763/cpol.2008.0533.
Shinyekwa, I., Kiiza, J., & Hisali, E. (2016). The Evolution of Industry in Uganda. *Learning to compete Working Paper, 9*(9), 191–210. https://doi.org/10.1093/acprof:oso/9780198776987.003.0010.
Surana, K., & Anadon, L. D. (2015). Public policy and financial resource mobilization for wind energy in developing countries: A comparison of approaches and outcomes in China and India. *Global Environmental Change, 35*, 340–359. https://doi.org/10.1016/j.gloenvcha.2015.10.001.
UNFCCC (2011) 'CDM – Executive Board Annex 5: GUIDELINES ON THE ASSESSMENT OF INVESTMENT ANALYSIS', p. 12. Available at: https://cdm.unfccc.int/sunsetcms/storage/contents/stored-file-20150817153801600/Reg_guid03.pdf.
Waissbein, O., Glemarec, Y., Bayrakta, H., Schmid, T.S. (2013) 'Derisking Renewable Energy Investment', ... (UNDP), New York, USA. Available at: http://scholar.google.ch/scholar?q=Derisking+Renewable+Energy+Investment+undp&btnG=&hl=en&as_sdt=0,5#0.
World Bank (2011) Africa's Power Infrastructure. The World Bank. DOI: 10.1596/978-0-8213-8455-8.
World Bank (2013) Enterprise Survey Uganda 2013. Available at: http://www.enterprisesurveys.org/data/exploreeconomies/2013/uganda.
World Bank (2018) 'Tax Revenue as % of GDP'.
World Bank (2019) About Us - Enterprise Surveys. Available at: www.enterprisesurveys.org/about-us.