Contracting structures in public procurement: Evidence from donor-funded electrification in Kenya

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Date: June 13, 2023
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Abstract

Unbundled contracting—the separation of project components across distinct contracts, as in 'design-bid-build'—is ubiquitous and consequential in public procurement, yet causal evidence on its impacts is limited. This paper uses policy and experimental variation to study two key contracting features—unbundling and enhanced monitoring—in Kenya's mass-electrification program. We exploit arbitrary procedural differences: the government bundled contracts at African Development Bank-funded villages but unbundled contracts and strengthened monitoring at similar, but World Bank-funded, villages. We identify a stark trade-off: unbundling and strengthened monitoring delayed connections by 16 months on average but improved construction quality by a sizeable 0.6 standard deviations. We implement additional randomized inspections (stratifying by funder) to show that, consistent with a simple model, combining bundling with strengthened monitoring can achieve similar quality improvements with fewer delays. Finally, we quantify how aggregate net benefits of contracting structures depend on project-specific attributes and the principal's preferences.

JEL codes: D73, F35, H5, L94, O19

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1 Introduction

Government agencies often rely on private firms to supply goods and services: public procurement spending amounts to 12% of global GDP (Bosio et al. 2022). But procuring public goods from private firms may misalign incentives, complicating a government's ability to ensure high-quality projects. Regulations can improve project outcomes but may also introduce bureaucratic inefficiencies or inhibit useful regulatory discretion (Williamson 1999; Hart et al. 1997; Bosio et al. 2022). Multilateral agencies also face this procurement problem: for instance, between 2000 and 2022 the World Bank financed more than 311,000 contracts with private sector contractors for the procurement of more than $185 billion in goods and services for more than 21,000 projects.

A little-studied feature of contract design is how to optimally assign project components across contracts: 'design-bid-build', for example, unbundles designs and construction across two separate contracts. Writing in Glaeser and Poterba (2021), Makovšek and Bridge (2021) state that "empirically we know relatively little about how procurement choices affect contract outcomes in (infrastructure) procurement," highlighting the importance of "contracts that bundle the design-and-build phase". In the context of foreign aid donors, unbundling is often intended to strengthen and enforce institutional procurement processes, but as a result, "operations risk being overburdened with over-defined and intrusive step-by-step process conditions" (World Bank 2005). Causal inference in this area is hampered by the infrequency, endogeneity, politicization, and complexity of large infrastructure projects, as well as measurement challenges.

This paper uses natural policy variation and experimental variation to generate causally identified evidence on this topic, which has been relatively rare to date. We do so in the context of the Last Mile Connectivity Project (LMCP), one of Kenya's largest recent public infrastructure projects at a cost of $600 million. Kenya is similar to many low- and middle-income countries in terms of regulatory stringency around procurement, favoritism, corruption, and delays (Bosio et al. 2022).

As part of the LMCP, in 2016 the Government of Kenya (GoK) selected 8,520 villages where all unconnected households within 600 meters of the existing grid would be connected to electricity. The program was implemented by Kenya Power (Kenya's government-controlled utility), which outsourced construction activities by running competitive auctions and administering dozens of contracts with private firms. All 8,520 LMCP villages were subject to identical eligibility, pricing, and network specifications, and all sites were transferred to Kenya Power ownership for operation after construction. However, two key features of the procurement procedures used by Kenya Power differed across the 3,200 sites funded by the World Bank (WB) and the 5,320 sites funded by the African Development Bank (AfDB). First, Kenya Power awarded 10 'bundled' contracts that included network designs, materials, and installation for villages funded by the AfDB. In contrast, Kenya Power awarded 29 unbundled contracts for villages funded by the WB (excluding metering and consulting contracts, which we discuss in more detail below). Second, Kenya Power conducted an additional round of inspections at sites funded by the WB before handover to the utility. As discussed in detail in Section 3, these were the only two meaningful differences between AfDB-funded sites and WB-funded sites.

The impacts of these contract features were unclear ex ante. During in-person interviews we conducted, WB representatives argued that their contracting approach would improve construction outcomes, while Kenya Power representatives feared that they would lead to administrative costs and delays without delivering substantive project benefits. The AfDB in turn agreed with Kenya Power that their extensive experience constructing and maintaining the grid in Kenya would enable them to ensure high quality even without unbundled contracting.

We first present a simple model to highlight key trade-offs of unbundled contracting and strengthened monitoring, which may be relevant for a wide range of infrastructure projects. When a principal (here, Kenya Power, representing the GoK) has imperfect information about realized project quality, contract unbundling can enforce minimum firm quality standards, improving project construction quality at the cost of possible delays and additional administrative burden. However, the model implies that strengthened monitoring can potentially enforce similar standards at lower cost, as this structure leverages bundled contractors' private information about potential subcontractors. If the principal is able to exert rigorous monitoring, unbundling contracts can under certain circumstances incur costs and delays with little additional benefit for project construction quality.

In this paper's main contribution, we use both natural policy variation and experimental variation to empirically identify the causal impacts of these different contracting features on project outcomes. First, we leverage a useful program feature: LMCP sites were assigned to be funded by either donor in a way that was arbitrary and can reasonably be thought of as quasi-random and without obvious regard to factors that would influence project outcomes. Neighboring villages were often funded by different donors: 95% of WB-funded sites in our sample are within 10 km (6 mi) of an AfDB-funded site. We conduct a battery of baseline balance tests using geographic, satellite, road, and census data to quantify any imbalance. WB- and AfDB-funded sites are balanced along most attributes and any selection appears uncorrelated with the outcomes of interest. Still, the econometric analyses include constituency fixed effects to account for local geographic and socioeconomic heterogeneity. Second, to evaluate the combination of bundled contracts with strengthened monitoring we implemented a randomized auditing intervention (with the support of partners at the WB, the AfDB, and Kenya Power) designed to mimic Kenya Power's additional inspections at WB-funded sites. Through in-person meetings, contractors were informed that key aspects of the completed construction at certain sites (randomly selected by the research team) would be measured and reported back to Kenya Power, the WB, and the AfDB.

An additional contribution of the paper is the collection of detailed and innovative data on construction and electricity connection quality, building on a small but growing literature emphasizing the importance of detailed infrastructure measurement (Olken 2007 is an early example). Our field teams tracked construction progress over multiple years for 380 LMCP villages through in-person visits and phone calls to village leaders, and then collected three types of on-the-ground data. First, we measured construction quality for key infrastructure components such as electrical transformers, poles, and wires, following Kenya Power engineering standards. Second, we deployed state-of-the-art sensors to measure minute-by-minute site-level power outages and voltage quality.

Third, we conducted socioeconomic surveys to understand connection experiences and energy usage among a representative household sample. We complement these data with the original Kenya Power procurement contracts. Finally, over the course of six years we conducted dozens of in-depth conversations with officials at Kenya Power, WB, AfDB, and private contractors.

The econometric analysis indicates that contracting procedures are highly consequential for project outcomes in terms of both costs and benefits. First, in terms of costs, construction at WB-funded sites is far slower and leads to fewer pole installations and household connections. By the end of tracking in May 2022, 70% of AfDB-funded sites had seen construction whereas only 62% of WB-funded sites had. Among sites where there had been construction, there are 12% fewer poles and 18% fewer customer connections per site at surveyed WB-funded sites, and importantly household meter activation at WB-funded sites is completed on average 16 months later than at AfDB-funded sites.

Second, in terms of benefits, WB procedures improve on-the-ground construction quality by 0.6 standard deviations on average, and 77% of WB-funded sites have higher measured quality construction than the median AfDB-funded site. Specifically, poles at WB-funded sites are 23% more likely to have all key attributes of a high quality pole: a pole cap, no crack, and a correctly installed strut and stay (when required). There are no measured medium-run differences in electricity reliability and voltage quality, though, and the impacts of WB procedures on household installation quality, cost, and energy usage are positive but modest in size and generally not statistically significant. Rather, the improvements in construction quality appear more likely to improve pole longevity and reduce long-term maintenance costs rather than improve service quality in the short-run.

To separate the impacts of unbundling and strengthened monitoring we turn to the randomized audit experiment. The data indicate that the audits have no impact at WB-funded sites, in line with the fact that those sites already faced additional inspections as well as unbundled contracting. In other words, this finding could hold because monitoring and unbundling are substitutes, or because additional monitoring has diminishing marginal returns. On the other hand, the audits cause significant improvements in installation quality at AfDB-funded sites. Households at these sites experience higher power quality as a result: the audit treatment halves the average gap between experienced and nominal voltage. Contractors installed 18% more poles (and 4% more customer connections, though this latter effect is not significant), and treatment households further report higher household connectivity and energy usage. Importantly, the audits increase the number of connections while being relatively inexpensive to administer and causing only short delays. In line with the model, these results suggest that additional monitoring for projects carried out using bundled contracts can generate similar quality improvements as the combination of contract unbundling and additional monitoring, but with fewer delays and at lower cost.

Finally, we assess the trade-off in costs and benefits for contract unbundling and monitoring. The average cost per new household connection is \$563 at AfDB-funded sites and \$728 at WB-funded sites (30% higher), driven by lower per-site costs and more new connections at AfDB-funded sites. The net impact of the various contract features depends on observable project attributes (such as the delay caused by unbundling) as well as unobservable ones (such as the funder's discount rate and time horizon, and the impact of improved construction quality on long term maintenance and replacement costs). Under a plausible range of assumptions, the net benefits could range from 7% of project costs in favor of bundling and less-intensive monitoring to a net benefit worth 4% of project costs in favor of unbundling and more intensive monitoring.

The empirical results point to a stark intertemporal trade-off. Policymakers may need to evaluate the long-term benefits of unbundled contracting and monitoring against the apparent short-term costs. Those with a higher time discount rate (or a shorter time horizon), or those implementing projects with compounding benefits, might prefer the timelier construction enabled by a streamlined bundled contracting approach. Conversely, in situations where maintenance costs are expected to rise quickly with poor quality, a delayed start might be worth the improved long-term outcomes. This perspective can also explain why some political agents, facing electoral or other domestic pressures, may prefer to work with donors whose procurement approach enables greater expediency.[1] In our study context, and in line with the model, combining contract bundling with enhanced audits delivers improved quality with little additional cost and delay, and might therefore be preferred to either of the AfDB and WB approaches we examine.

Any relatively short- to medium-run analysis, like ours, has obvious limitations. Procurement procedures may generate additional positive benefits over time that we cannot measure, such as strengthened government institutional capacity. Like most other research projects, we are also unable to directly measure leakage of funds, and this may be an important concern in some contexts. However, to the extent that increased leakage at AfDB-funded sites (where there was less stringent monitoring) would have reduced the quantity of completed construction, we find limited evidence of this: in fact, AfDB-funded sites appear if anything to complete more connections at lower average cost than equivalent WB-funded sites.

These findings contribute to a debate about donor conditionality that dates back at least to the 'Washington Consensus' era in the 1980s (e.g. Mosley 1987; Hermes and Lensink 2001; Easterly 2002; Williamson 2009; Temple 2010; Archibong et al. 2021). World Bank (2005) provides a thorough review of the evolution of donor conditions, which increasingly emphasize procedures (rather than policies), though the resulting costs and benefits have been subject to controversy. Recent research suggests procedural conditionality may cause politically motivated delays and incur costs that exceed benefits (Kersting and Kilby 2016; Kilby 2013). And concerns around political interference and corruption remain relevant (even if we cannot directly evaluate them in our setting): Andersen et al. (2022) find that up to 10% of WB financing is transferred to offshore financial havens in the months after a transfer. Related work that empirically evaluates on-the-ground construction of development projects in Africa includes Williams (2017), Marx (2018), Rasul and Rogger (2018), and Moscona (2020).

[1] For example, the Chinese government's approach to providing foreign aid includes "not interfering" in local politics (State Council 2014), and streamlining procurement procedures. The limited oversight has generated concerns about construction quality and rampant corruption (The Economist, 2017; Mihalyi et al. 2022; Dreher et al. 2021; Isaksson and Kotsadam 2018; Ping et al. 2022; Malik et al. 2021; The Africa Report, 2022).

Mass electrification programs are widespread in LMICs, but poor construction quality can harm power quality: Blimpo and Cosgrove-Davies (2019) find that in some countries, most connected households "reported receiving electricity less than 50% of the time," potentially undermining the economic activity that household connections were intending to stimulate. Lee et al. (2020) find that transformer outages in rural Kenya frequently last more than four months, which may contribute to the low uptake and limited impacts of household electricity that they and Kassem et al. (2022) find. In India, Burlig and Preonas (2023) find that improved electricity reliability increases the impacts of rural electrification in larger villages. To the extent that low quality infrastructure exacerbates poor power quality and reduces the economic benefits of electrification, identifying opportunities to improve construction quality—including through specific procurement contracting conditions—may lead to meaningful improvements in economic outcomes.

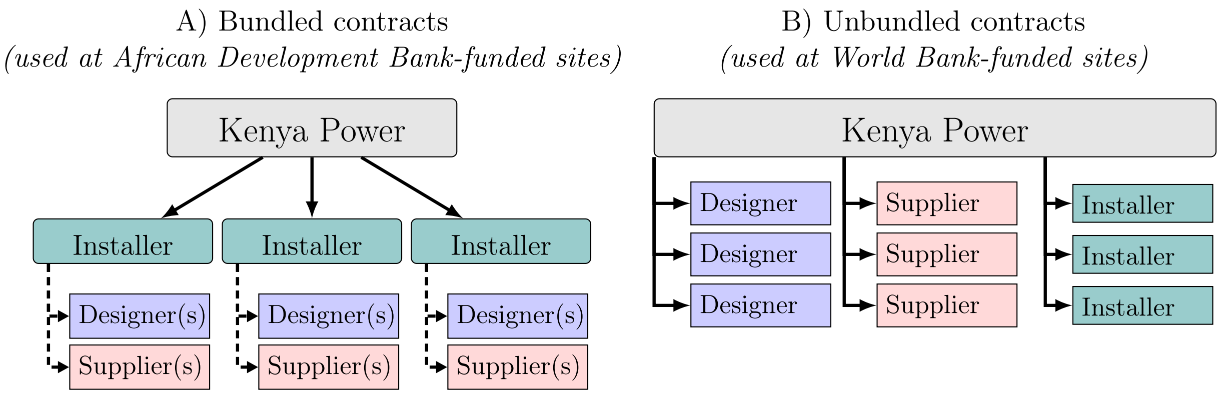
2 Framework for contract (un)bundling and monitoring

A large economics literature has studied the public procurement of goods and services from the perspectives of contract theory (Hart et al. 1997; Bosio et al. 2022; Tadelis 2012; Levin and Tadelis 2010; Williamson 1999) and auction mechanism design (Kaplan and Zamir 2015; Bergemann and Välimäki 2019; Hortaçsu and McAdams 2018). However, few have studied how the multiple components that many projects consist of—such as design and construction—should be organized into contracts. For example, these could be bundled into one contract (known as 'design-and-build' in some contexts) or a principal could unbundle these and have one contractor create the design and a different contractor build the resulting design (known as 'design-bid-build'). A somewhat related literature studies bundling in contexts where the bundling decision is made by the seller in response to heterogeneous buyer preferences (Daskalakis et al. 2017; Manelli and Vincent 2006; Rochet and Stole 2003). However, research on bundling by the buyer, as in our setting, is scarce (Hoppe et al. (2013)'s experiment among 400 university students is one notable exception). Empirical evidence from realized projects is scant, despite the ubiquity and importance of this decision in public procurement. Makovšek and Bridge (2021) state, "it is still not fully clear whether contracts that bundle the design-and-build phase outperform the traditional design-bid-build contract, where the two phases are procured separately."

Our main contribution to this literature is empirically studying the bundling of the design, supply, and installation components of a major real-world infrastructure project in a high-stakes public procurement context using natural and experimental variation and granular, independently-collected construction quality data. Here we first lay out a framework that highlights the key conceptual issues and potential trade-offs that motivate the econometric analysis.

Consider a principal who has a project that it wants to contract out to one or more firms. The project consists of three components: design, obtaining supplies, and installation. Figure 1 shows this framework in our context. 'Bundling' is the case where the principal only awards installation contracts, and installers are responsible for procuring designs and supplies through subcontracts

Figure 1: Bundled and unbundled contracting structures



Schematic of the two types of contracting methods used for the Last Mile Connectivity Project. In the bundled method (Panel A), the principal contracts with installers who procure designs and supplies. In the unbundled method (Panel B), the principal procures components directly. Solid lines represent contracts issued by the principal. Dashed lines represent subcontracts issued by an installer. In the study setting, the principal (Kenya Power) used a bundled structure at African Development Bank sites (awarding 10 bundled contracts plus 2 for consulting and meters) and an unbundled structure at World Bank sites (awarding 29 unbundled contracts for designs, supplies, and installation, plus 6 for consulting and meters).

(Panel A). 'Unbundling' is the case where each contract contains only one component (Panel B).

Unbundling could affect outcomes in numerous ways. For example, under unbundling, designs must be fully specified to enable procurement of specific supplies. Such full specification may be inefficient, as contractors may benefit from having some discretion: under bundling, installers can adjust designs and supplies if unforeseen issues arise. Bundling also avoids the double mark-up problem, though at the same time it may reduce competition if entry requirements are set higher for larger contracts (such as those under the bundling approach). In some contexts, the contractor operates the infrastructure for a fixed period prior to transferring ownership back to the principal, which brings additional considerations (not relevant here since all sites were handed over to Kenya Power for operation upon completion). In other cases a principal can choose to conduct activities in-house rather than contracting them out. For tractability we limit the framework to the features at play in our empirical context and leave research on these remaining mechanisms for future work.

To fix ideas, assume the principal wants the three components (designs, supplies, and installation) to be carried out by three firms selected from a continuum of firms $\gamma_i \in [0, \infty)$ defined by firm type, where higher types produce higher quality at higher cost. Firms are selected through an auction, and only firms exceeding an exogenously set firm type threshold $\bar{\gamma}$ are eligible to bid (in our setting, bidders must meet uniform global WB and AfDB documentation requirements).[2] Each firm also chooses how much effort $e_i \in [0, \infty)$ to exert. The quality of each component is determined by the firm type and the effort that firm exerts: $q_i = \gamma_i + e_i$.

Increasing firm type γ_i and effort e_i incurs convex costs $c(\gamma_i)$ and $d(e_i)$. For a given level of quality q, denote $\gamma^*(q)$ and $e^*(q)$ to be the cost-minimizing combination of effort and firm type, with $\gamma^* > \bar{\gamma}$. We assume perfect competition, with firms bidding $b_i = c(\gamma_i) + d(e_i)$ (a reasonable

[2] An alternative model could endogenize this threshold: lower monitoring or contract unbundling might change the optimal threshold. We omit that here as the threshold is exogenously set by donor policy in this context.

approximation in our context, where most auctions attract a large number of bids from many local and international firms).

The principal faces two problems. First, it has imperfect information about firm types, and can only observe whether a firm exceeds the minimum threshold (installers, on the other hand, have perfect information about designer and supplier types[3]). Second, since firms decide how much effort to exert after contracts have been awarded, the principal must find a way to incentivize effort.

The principal has two contracting tools. First, it can choose to offer either one bundled contract ($t = 1$) or three unbundled contracts ($t = 3$). Second, the principal can implement either low ($m = L$) or high ($m = H$) monitoring. Under low monitoring, all contractors are paid regardless of realized quality. In this case, firms exert no effort, and quality simply corresponds to their firm type: $q_i = \gamma_i$. Under high monitoring, contractors are only paid if the quality of the component(s) included in their contract meets a quality threshold. The principal implements the auction as follows (Appendix C presents this framework more formally):

(P1) The principal chooses and announces the two auction parameters (t and m).

- If the contracts are unbundled, the principal runs three sequential auctions.
- If the contract is bundled, the principal runs one auction (for installation).

(A1) Each eligible firm decides whether or not to bid. If a firm chooses to bid, its bid amount corresponds to its type and the level of effort it will want to exert: $b_i = c(\gamma_i) + d(e_i)$.

(P2) The principal identifies the lowest eligible bid(s) as the auction winner(s). If the contract is bundled, the winner then selects a designer and supplier with full discretion (i.e. they could choose firm types below the threshold: $\gamma_i < \bar{\gamma}$).

(A2) Each firm chooses an effort level and realizes their component quality.

(P3) With low monitoring, all firms are paid regardless of realized quality. With high monitoring, the principal only pays each contractor if the quality of the component(s) included in their contract meets the relevant minimum threshold (for bundled contracts, all three component thresholds must be met).

While unbundling and higher monitoring improve quality, they incur administrative costs $\kappa(m, t)$, which are increasing in both arguments. Furthermore, monitoring incurs delays both directly (the monitoring itself takes time) and indirectly (incurring greater effort may cause firms to complete activities more slowly), and unbundling causes delays by adding administrative and coordination tasks associated with conducting three sequential sets of auctions rather than a single set of auctions. These delays lower the project's future welfare gains W according to a function $D(m, t, \delta) < 1$, where δ denotes the principal's intertemporal discount rate. When selecting t and m the principal wishes to maximize net benefits, factoring in these costs and delays, contract costs b_i, and long-term maintenance costs M, which decrease with aggregate project quality Q (the sum of the qualities

[3]Conducting installation using another firm's designs and supplies provides a level of insight into that firm's type and effort that cannot be achieved by the principal through even very careful monitoring. Furthermore, in practice many installers collaborate with the same designer or supplier much more frequently than the principal does.

of the three components: $Q = q_a + q_b + q_c$). Maintenance costs can be thought of as the expenses needed to maintain project benefits at level W over the lifetime of the project; higher quality construction lowers these expenses.

$$\text{Project Net Benefits} = \underbrace{D(m,t,\delta)W}_{\text{Welfare gains}} - \underbrace{\kappa(m,t)}_{\substack{\text{Administrative}\\\text{costs}}} - \underbrace{\sum_{i=1}^{t} b_i(m,t)}_{\substack{\text{Contract}\\\text{costs}}} - \underbrace{\sum_{y=1}^{Y} \delta^y M(Q(m,t))}_{\substack{\text{Long-term}\\\text{maintenance costs}}} \qquad (1)$$

The principal's optimal choice of monitoring and (un)bundling will depend on, for example, the delays incurred, their discount rate, and the effect of quality on long-term maintenance costs.

This framework provides two intuitive implications, which we derive formally in Appendix C and illustrate graphically in Figure A1. The first is that, compared with bundled contracts that receive low monitoring, unbundled contracts that receive high monitoring unambiguously result in higher type firms and higher effort, which generate higher project quality, incur more delays, and increase the cost of the minimum bid.[4]

A perhaps less immediate implication is that, conditional on being accompanied by high monitoring, bundled contracting will unambiguously incur fewer delays than unbundled contracting while still attaining similar quality. The intuition for this is straightforward. In the absence of high monitoring, bundled contractors choose cost-minimizing design and materials firms. However, when faced with high monitoring, bundled contractors have an incentive to select design and materials firms of type γ^* to minimize costs (and use their private information and discretion to do so). Meanwhile, under high monitoring, unbundled contractors with the cost-minimizing firm type and effort for the given quality threshold (γ_i^*, e_i^*) will offer the cheapest bids. The bundled and unbundled auctions would thus both select optimal firm types and incentivize optimal effort levels for all three components, resulting in identical project quality despite the additional delays caused by unbundling. Put differently, the effect of high monitoring is so much greater under bundled contracts that it compensates for the fact that bundling generates worse outcomes under low monitoring.

This paper uses natural policy variation to empirically study the first implication. To study the second implication, we implement a randomized monitoring intervention (stratifying across the policy variation) that allows us to observe bundled contracts in a high monitoring setting. Section 4 describes these identification strategies in more detail and Section 7 uses the empirical results to quantify the trade-offs from Equation 1 in our study context.

This framework can be used to evaluate alternative incentive structures that we do not observe in our setting. For example, a principal might consider only monitoring after project completion. According to the model, unbundling would generate worse quality than bundling in this case (in

[4]High monitoring incentivizes effort since firms will not get paid if they do not meet the quality threshold. It also allows the principal to identify firms of type γ^* because they will have the cheapest bids (lower type firms would need to incur significantly higher effort costs to realize the same quality). Note that the more direct effect of unbundling (allowing the principal to directly constrain design and materials firms to only those that meet the eligibility threshold) becomes obsolete when unbundling is combined with high monitoring, as lower type firms would have to expend significant effort to compensate for their low types and thus will not have the lowest bid.

addition to incurring higher administrative costs) because it would not incentivize the design or supply firms to exert effort. Subsection 7.3 touches on these additional implications.

3 Background

In May 2015, Kenya's President announced the launch of the LMCP, which aimed to connect 70% of households to electricity by 2017 and achieve universal access by 2020, starting from 25% in 2009 (KNBS 2009). While these ambitious goals were not met, nationwide household electricity access increased rapidly and was reported to have reached 70% a few years later in 2019 (KNBS 2019).

Construction was outsourced to private sector contractors, with construction activities wholly managed by Kenya Power: they issued, reviewed, and awarded contracts; managed contractors and consultants; and conducted inspections independently. $133 million in procurement contracts were financed by the WB while $154 million in contracts were financed by the AfDB.[5] As discussed in detail below, there were only two meaningful differences between the procedures Kenya Power used at sites being constructed under WB and AfDB funding: Kenya Power used bundled contracting for sites funded by the AfDB but unbundled contracting for sites funded by the WB, and Kenya Power administered an additional round of inspections at WB-funded sites.

3.1 Political background

International development banks routinely finance development projects while having little to no direct involvement in implementation. Rather, recipient governments typically independently procure goods and services from private sector contractors. For instance, between 2000 and 2022 the WB financed more than 311,000 procurement contracts across more than 21,000 projects, including 2,315 projects related to energy or power (with 754 in Sub-Saharan Africa). While certain procedures can vary depending on circumstances, extensive and largely uniform WB regulations detail the management and disbursal of these funds:

> "Borrowers using the Regulations spend billions each year procuring works, services, or goods from third-party suppliers, contractors and consultants... in over 170 countries across the globe [and] range from highly complex infrastructure, cutting edge consultancy, major pieces of plant/equipment, and high tech information technology."
>
> World Bank Procurement Regulations for Borrowers (2020)

Over the past two decades, international donors have increased their efforts to moderate the cost of complying with these regulations by streamlining and harmonizing their policies. WB and AfDB regulations now have significant overlap, with for instance harmonized master procurement documents and standard bidding documents that are required for projects financed by WB or AfDB

[5]Later, the LMCP was to receive support from the European Investment Bank, the Agence Française de Développement, and the European Union (Kenya Power 2016a). This paper focuses on activities funded by the WB and by Phase I of the AfDB, which we refer to jointly as Phase I of the LMCP.

funding (WB 2014, AfDB 2014). One of the goals of these procurement regulations is to curtail corruption and political abuse.[6]

3.2 Kenya Power auction and procurement procedures

The LMCP was a single nationwide project, implemented entirely by Kenya Power under a uniform set of specifications. There are around 60,000 electrical transformers across Kenya, which convert high- and medium voltage power lines to low voltage (LV) lines that can connect households. In rural areas, transformers are often located in villages where very few households were connected at the start of LMCP (Lee et al. 2016). Kenya Power in consultation with the Ministry of Energy and members of parliament selected 8,520 such transformers for the LMCP, targeting an equitable regional distribution across Kenya. The objective was to connect all unconnected households located within 600 meters of an LMCP transformer by extending the local LV network; at most LMCP sites, between 20 and 100 unconnected households were eligible. Connecting all unconnected households in a village at the same time—referred to as 'maximization'—was supposed to generate cost efficiencies by leveraging economies of scale. Eligible households benefited from a reduced electricity connection price, from the previous \$350 down to \$150, as well as from the ability to pay it off in monthly installments, with no upfront down-payment (Subsection 3.6 discusses this further). The program was also touted as reducing the red tape associated with new electricity connections: Kenya Power contractors would visit households to initiate the connection process, with minimal effort for households. Appendix D provides additional background information.

Kenya Power administered numerous competitive auctions for construction contracts with domestic and international private-sector firms. Uniform tender documentation contained detailed technical specifications for the procurement and installation of poles, wires, conductors, fuses, and meters. These specifications were harmonized across donors to simplify compliance. Requests for proposals were released widely through standard channels, with many contractors routinely bidding on contracts financed by different donors. WB and AfDB can both debar contractors with egregiously poor performance, and debarment generally applies globally. Under-performance can lead to disqualification from contracts in other countries, by other donors, and in other sectors. Independent audits can therefore be a meaningful threat for contractors, which we exploit in the randomized audits treatment, discussed in Subsection 4.2.

Importantly for this paper's empirical approach, the AfDB financed the maximization of 5,320 of the LMCP transformers and the WB financed the maximization of 3,200 (Kenya Power 2017, 2016a).[7] LMCP transformers were assigned to be funded by the WB or the AfDB in a seemingly arbitrary and ad hoc manner, with neighboring villages often being funded by different donors;

[6]There was widespread (and apparently well-placed) concern that political interference and corruption within Kenya Power could jeopardize LMCP project outcomes (The Star 2018; Kenya Power 2018b, 2020; ESI Africa 2020; Lee et al. 2020). Kenya Power's CEO Ken Tarus and his predecessor Ben Chumo were arrested in July 2018 and—alongside several other senior Kenya Power officials—faced charges relating to corrupt procurement practices and bidding collusion (Reuters 2018; The Nation 2022; Business Daily 2018; The Nation 2021).

[7]The WB funded new transformers at 1,000 additional sites. Those projects are excluded from this paper.

Section 4 discusses this assignment process in detail. Kenya Power awarded a total of 47 contracts: 39 for implementation, five for consultants to manage contractor relationships, and three for uniform electricity meters. While Kenya Power's technical requirements were identical across all 39 implementation contracts, and AfDB and WB procurement procedures were identical along most dimensions, there were two key differences between the donors: the degree of contract bundling, and the extent of monitoring. The next two sub-sections discuss these differences in turn.

3.3 Contract bundling

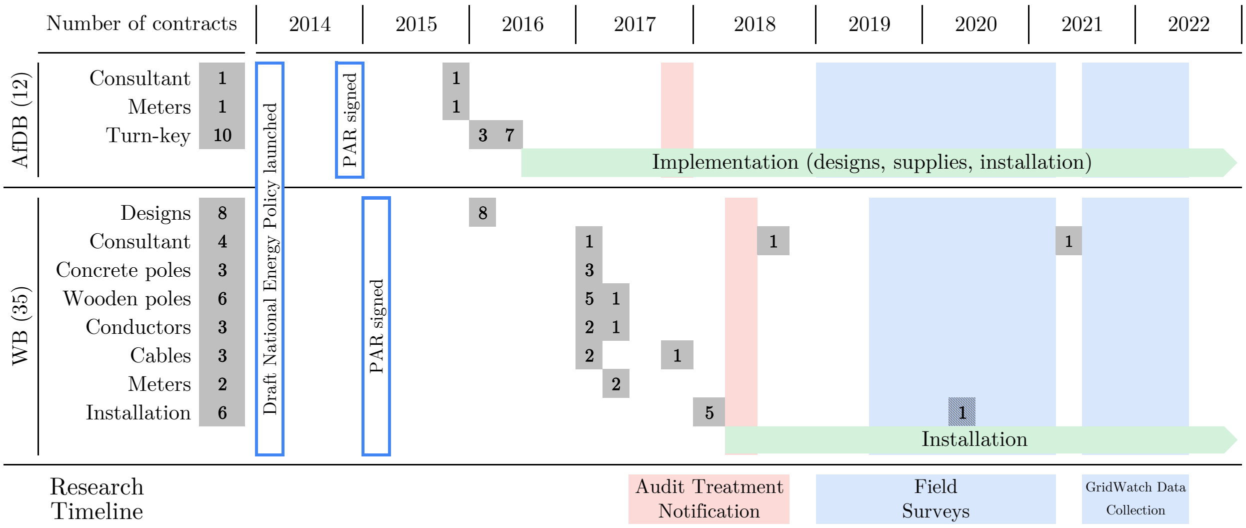
For sites funded by the AfDB, Kenya Power used a bundled contracting approach often referred to in this context as 'turn-key' (also referred to as 'design-and-build' in some contexts), which "provides for full design, supply, erection and commissioning of the works by a single contractor at a fixed lump sum price" (AfDB 2018). Each of the ten turn-key contracts comprised the entire construction process of all LMCP sites in one of ten geographical clusters of counties nationwide. This process included designing an efficient extension of the LV network to reach unconnected households, procuring the necessary materials, and final installation of these materials. Together with a metering contract and a consulting contract, Kenya Power awarded 12 contracts that were funded by the AfDB.

On the other hand, Kenya Power used an unbundled contracting approach for LMCP sites funded by the WB. Kenya Power first auctioned and awarded eight contracts for designs detailing the proposed LV network extensions across eight sets of sites. They then issued 15 separate contracts to procure materials: six for wooden poles, three for concrete poles, three for conductors, and three for cables. Finally, they issued six different contracts for installation at all LMCP sites located in one of six geographic clusters of counties (again nationwide with extensive geographic overlap with the regions covered by AfDB contracts). Kenya Power also awarded two metering contracts and four consulting contracts, for a total of 35 contracts funded by the WB.

These procurement structures are not fixed by donor across all the projects they finance globally, and may depend on context. The AfDB and WB decisions to use bundled and unbundled contracting, respectively, for the LMCP were made independently ex ante, informed by discussions with Kenya Power and donors' experiences in Kenya. In other sectors and countries, the WB may require bundled contracting, and vice versa for the AfDB. WB (2020) states that the "selection of contract types and arrangements takes into account the nature, risk, and complexity of the procurement, and [Value for Money]". AfDB (2018) similarly states that, "In complex cases, a 'turnkey' or 'design-and-build' approach may be more appropriate." Neither funder specifies a strict rule on how this decision is to be taken, but in this case—fortunately for the analysis in this study—they reached different conclusions about the appropriateness of particular contracting approaches.

Figure 2 presents a timeline of these activities. The Draft National Energy Policy (2014) targeted universal electricity access by 2020 adding that they would "seek funding from development partners." According to the WB and AfDB Project Appraisal Reports (PARs), signed October 2014 and March 2015, respectively, contract signing was to take place in early 2016 (AfDB 2014;

Figure 2: Dates of contract signing, construction, and research activities by multilateral



Timeline of contracting and research activities. The Draft National Energy Policy (2014) spurred government discussions with the African Development Bank and the World Bank, which signed Project Appraisal Reports (PARs) in October 2014 and March 2015, respectively, signalling the official project launches. Sites that had been completed prior to the audit treatment notification in late 2017 were excluded from the RCT sample. Surveys were conducted after construction completion. The date of one consulting contract is unknown.

WB 2015). By mid-2016, Kenya Power had signed all 12 AfDB-funded contracts (Kenya Power 2015a). Kenya Power signed the six WB-funded design contracts by March 2016, but materials and installation contracts were only signed starting February and November 2017, respectively. Both PARs indicate expected project end dates at the end of 2019.

3.4 Monitoring and oversight

In the context of the LMCP, oversight can be split into four channels (listed out below). While WB and AfDB procedures were largely similar across the first three channels, WB's procedures were more onerous than the AfDB for the fourth.

In terms of largely comparable channels, first, each donor required similar materials inspections. A team representing Kenya Power's LMCP, supply chain, and operations departments would visit contractors' facilities to inspect materials. The only difference here was that the WB required that each pole be physically marked such that they could be easily verified upon arrival at Kenya Power storage facilities. Still, WB and AfDB spot checks both approved more than 99% of procured poles.

Second, Kenya Power directly monitored contractor activities. Kenya Power would combine and summarize the contractors' monthly summary progress reports and share these with funders. At least twice per year, each funder conducted a similar week-long 'supervision mission' consisting of meetings with senior Kenya Power and Ministry of Energy officials in Nairobi and site visits in nearby regions, resulting in a 'supervision mission report.'

Third, the AfDB and WB both required 'no objection' approvals at key stages. Interviews with staff suggest that the WB's checks were slightly more intensive, but that AfDB checks sought to achieve the same compliance goals.

Fourth, once construction at a site was complete, the consultant, the contractor, and Kenya Power would do a joint inspection and sign a "Joint Measurement Certificate" (JMC) to certify that construction was complete and that the site could be handed over to Kenya Power for activation. However, WB and AfDB inspection procedures contained one notable difference. Prior to the inspection that would produce the JMC, the consultant assisting with WB-funded sites conducted an additional on-site inspection with the contractor (but without a Kenya Power representative) to produce an "Inspection Report" (IR), listing any observed construction issues.[8] IRs were usually conducted ahead of the JMC, allowing contractors to fix remaining issues before the JMC visit.

3.5 Contractor and subcontractor selection

Kenya Power awarded the 47 contracts to 41 unique contractors, with six contractors winning two contracts each. Other than a single metering contractor (for the purposes of harmonization with Kenya Power's IT systems), there was no overlap between bundled and unbundled contractors.

As is common under bundled contracting, turn-key contractors often procured designs, materials, and installation from subcontractors. There was partial overlap between the contractors awarded WB-funded supplies contracts, and the subcontractors from which turn-key contractors procured goods or services (as described in Subsection 7.3). While this overlap could have affected the timing or quality of procured supplies, this does not appear to have been a meaningful issue in practice.[9]

Donor practices may also cause firms with certain characteristics to be more likely to bid on certain types of contracts. Speculatively, projects with more stringent requirements could attract firms with more efficient operations or better compliance teams. As illustrated by the model, this can be viewed as a mechanism through which procurement regulations could affect project outcomes rather than necessarily as a threat to econometric identification.

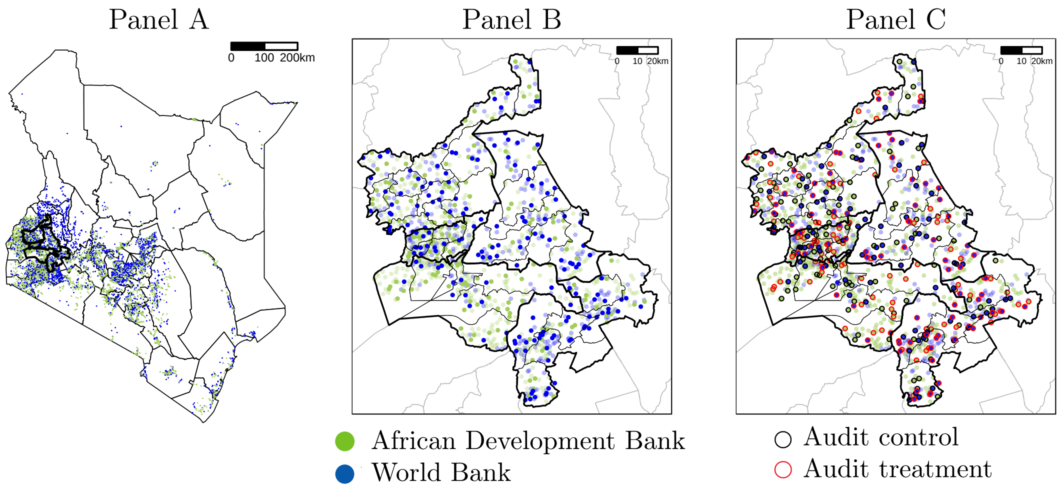
3.6 Household investments

To use electricity, a household needs to organize wiring for power sockets and light switches. The household surveys we administered indicate that households connected prior to the LMCP spent on average $125 on internal wiring. Kenya Power therefore decided to provide low-income households with a 'ready board', a standard electrical panel that would satisfy basic wiring requirements. Yet the roll-out of ready boards was not perfect. Of the 160 households we surveyed who were physically connected to the grid but where electricity had never actually flowed, 45% said it was because they had not yet completed their internal wiring. While informal or illegal electricity connections are common in urban Kenya (for instance, by tapping existing wires), they are rare in the lower population density rural areas where the LMCP was implemented (see Appendix D).

[8] Comments from the IRs include, for example, "pole caps are poorly installed" and "the strut pole bolt is not secured with nut and washers," often accompanied by a photograph.

[9] For instance, if AfDB-funded contracts monopolized high-quality poles, this could in theory affect procurement for poles at WB-funded sites. However, securing supplies does not appear to have been a source of delay: if anything, storage was more of a concern. Many of the plausible concerns here would go against our results.

Figure 3: Sites by funding source and audit treatment status



Panel A maps sites selected for the Last Mile Connectivity Project nationwide, with the five counties where we conduct engineering and socioeconomic surveys—Kakamega, Kericho, Kisumu, Nandi, and Vihiga—marked in bold. Panel B enlarges these five counties and adds within-county constituency boundaries. There appears to be limited spatial clustering by donor. Dark (light) sites are (not) included in our sample. Panel C shows audit treatment and control sites circled in red and black, respectively. Uncircled sites are not in the RCT sample.

4 Research Design

The nationwide distribution of LMCP sites is presented in Panel A of Figure 3. We exploit the quasi-random assignment of sites to funding by WB or AfDB to estimate the causal impact of donor contracting structure on project outcomes. To examine how monitoring affects project outcomes, we then implement a randomized audits scheme. We discuss these in turn.

4.1 Quasi-random assignment of sites to aid donors

Each site was assigned to be financed by either the WB or the AfDB. While geographic clustering might have generated economies of scale, each funder sought to fund sites nationwide, possibly to avoid the appearance of political bias. Of Kenya's 290 electoral constituencies, 265 contain at least one LMCP site and 210 contain at least one AfDB-funded site and one WB-funded site.[10]

From June 2016 through July 2022, members of the research team met extensively with key Kenya Power personnel, including the General Manager for Connectivity, responsible for all of Kenya Power's new electricity connections, and the two Project Managers who oversaw the nationwide LMCP. We read correspondence between Kenya Power and dozens of members of parliament deciding which transformers each phase of the LMCP would include. Overall, we consistently observed that the assignment process among the donors appeared to be ad hoc and did not follow any particular allocation rule. Given that the overall mandate—to connect all households within 600 meters of a transformer—was identical regardless of which donor funded a site, Kenya Power and the GoK did not appear to see any obvious strategic benefit in having a particular transformer

[10] A constituency is a relatively small geographic unit with average population of approx. 185,000.

Table 1: Geographic balance of World Bank- and African Development Bank-funded sites

	Road Distance		VIIRS Radiance		Land Gradient	
	(1)	(2)	(3)	(4)	(5)	(6)
World Bank (=1)	-0.23	-1.25	-0.01	-0.03	0.99***	0.57**
	(2.29)	(1.38)	(0.06)	(0.06)	(0.31)	(0.24)
Observations	347	347	51214	51214	347	347
Month FE	No	No	No	Yes	No	No
Constituency FE	Yes	Yes	No	Yes	No	Yes
AfDB Mean	60.49	33.64	.41	.41	4.36	4.36
Outcome variable	Minutes	KM				

Columns (1) and (2) estimate distance in driving minutes and in kilometers, respectively, from each of the 380 study sites to the nearest 'major town' (WRI 2007) as calculated in HERE (2022). Columns (3) and (4) estimate monthly average site-level nighttime radiance measured using VIIRS averaged across the 600 meter radius (Elvidge et al. 2017). Standard errors are clustered by site (Figure A2 shows the time series). Columns (5) and (6) estimate average site-level land gradient recorded using the 90-meter Shuttle Radar Topography Mission Global Digital Elevation Model. Month and constituency fixed effects included where indicated. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

funded by one donor or the other. Of course, this perspective was based on interviews and anecdotal evidence, but the same pattern emerges using systematic data below.

The causal identification strategy leverages this quasi-random allocation of each LMCP site to a funder. Of the 8,520 nationwide LMCP sites shown in Panel A of Figure 3, 1,099 are located in Kakamega, Kericho, Kisumu, Nandi, and Vihiga, magnified in Panel B. We collected detailed on-the-ground assessments in these counties, which comprise 36 constituencies, of which 35 have at least one WB-funded site and at least one AfDB-funded site. We include constituency-level fixed effects in regressions to account for local differences. In line with explanations provided by the electric utility, there does not appear to be stark spatial clustering by donor: 95% of WB-funded sites in this sample are located within 10 km of an AfDB-funded site (and vice versa). Of the 1,099 LMCP sites in the region, we randomly selected 380 sites as the study sample, stratifying selection by constituency and funder to improve statistical power.

The deliberate allocation of sites to WB or AfDB funding by Kenya Power employees—for example, to speed up construction or improve construction quality in some areas relative to others—could be a threat to the econometric identification strategy if local site characteristics influence the quality or timeliness of construction. While we have no evidence of this, possible reasons could include partisan influence, local economic growth expectations, or personal bias and favor. We conduct numerous balance tests to quantify any such differences. First, Table 1 tests for balance using three independent datasets. 80% of sites are between 13 and 58 kilometers from the nearest large town, and columns (1) and (2) show that remoteness is balanced across WB- and AfDB-funded sites. Columns (3) and (4) show that pre-LMCP nighttime radiance levels (which reflect local electricity usage and economic activity) were statistically indistinguishable (Figure A2 shows that pre-LMCP trends were similarly indistinguishable). Table 2 shows that the fraction of WB-funded sites in a ward is not correlated with pre-LMCP ward-level socioeconomic characteristics.

Despite these similarities, there are some modest differences between WB- and AfDB-funded sites. First, column (6) of Table 1 indicates that WB-funded sites have a 13% higher average land

Table 2: Balance in 2009 census socioeconomic characteristics by number of LMCP sites per ward

	Share of LMCP Sites that are WB-funded	N	Dep. Var. Mean (SD)
Age 14 or Under	-1.34	170	51.39
	(0.89)		(3.76)
Consumption	157.02	170	3063.59
	(300.38)		(1285.98)
Primary Education	-1.19	170	61.54
	(1.18)		(4.54)
Secondary Education	2.06	170	19.65
	(1.68)		(6.50)
Solar Home System	-0.19	170	1.10
	(0.16)		(0.71)
Electricity	4.49*	170	6.96
	(2.52)		(10.37)
High-Quality Wall	0.84	170	13.06
	(2.61)		(9.24)
High-Quality Roof	-0.68	170	81.52
	(2.72)		(12.04)
Population	563.90	170	22801.28
	(2194.68)		(6158.08)
Land Area (sq km)	16.94*	170	62.70
	(9.89)		(44.15)
Joint F-test	p-value = .05		

This table tests for correlations between the share of Last Mile Connectivity Project (LMCP) sites in a ward allocated to World Bank (WB) funding and baseline characteristics, at the ward level, among wards with at least 1 LMCP site. Row 1 shows population share aged 14 years or younger. Row 2 shows monthly consumption expenditures per capita in Kenya Shillings (Ksh). Rows 3 and 4 show primary and secondary school completion rates, respectively. Rows 5–8 show percentage of households with solar, electricity, a high wall and roof quality, respectively. All regressions include constituency fixed effects. Data sources: Kenya National Bureau of Statistics (2006; 2009). $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

gradient (when including constituency fixed effects). Second, Table 2 suggests a difference in the fraction of households with an electricity connection pre-program, though the magnitude is minor: a (large) shift of 25% in the proportion of local LMCP sites funded by the WB (rather than AfDB) is associated with an approximately 1.1 percentage point higher baseline household electricity connection rate. Finally, there are slight differences in nearby public facilities: for instance, 23% of AfDB-funded sites versus 8% of WB-funded sites were located near a secondary school (Table A1). Extensive robustness checks confirm that the timing and construction quality outcomes are uncorrelated with land gradient and facility type. The main results presented below are constant across the entire support of land gradient and facility type (Subsection 6.6). Still, where relevant, regressions control for variables that exhibit some baseline differences.

4.2 Randomized audits

We implemented a randomized audit treatment closely mirroring the Inspection Reports Kenya Power completed at WB-funded sites (discussed in Subsection 3.4), to disentangle the impacts of unbundling and additional inspections. After construction at a site was completed, enumerators hired by the research team visited each site to inspect the electricity network according to specifications we developed in collaboration with retired Kenya Rural Electrification Authority electrical engineers. Of the 380 study sites, we randomly assigned 190 to treatment and 190 to control, stratifying by constituency and funder. Panel C of Figure 3 maps treatment and funder assignments.

The randomized audits were implemented in collaboration with Kenya Power and the two funders, as follows. During in-person meetings set up for this purpose, senior Kenyan research personnel notified contractors that an independent, international team of engineers would audit specific sites once construction was complete. They provided a written notice to this effect, signed by senior management at Kenya Power, the WB, and the AfDB (Figure A4), and attached a list of sites in their contract region that would be audited. The letter also specified four technical aspects of construction that would be inspected: the distance between poles, line sag, the quality of connection between transformer and LV wiring, and power reliability.

Unbeknownst to the contractor, the list of sites that they were told would be audited was a randomly selected subset of the full set of sites where our research team conducted endline engineering surveys (described in Subsection 5.1). Given the random selection of sites communicated to the contractors, any difference in construction outcomes between the sites about which contractors were notified and the control sites can be attributed to contractors' response to the audits. Figure 2 displays the timeline of audit treatment notification and the engineering surveys.

In communications with WB officials (in both Washington D.C. and Nairobi), the WB indicated they would take contractor-level outcomes at both WB- and AfDB-funded sites into account in future contracting. This setup can therefore be thought of as a repeated game environment where there are real consequences to contractor performance: many contractors depend on their ongoing relationships with international donors. To remind contractors of this incentive, the notification letter emphasizes the issue of future contracts.

While the research team did not widely share its activities, it is possible that some contractors (correctly) believed that control sites might also be audited. If treatment impacted a contractor's general operations across treatment and control sites, this would cause us to underestimate the impacts of the audit treatment. Conversely, audit effects may be overestimated if contractors shifted construction effort from control sites to the audit treatment sites. However, such spillovers are likely to be small: on average, only 7.6% of a contractor's sites were randomly selected for audits.[11]

4.3 Treatment interactions

The interaction of experimental and natural policy variation allows us to empirically investigate how unbundling and monitoring may interact, as discussed in Section 2. Comparing AfDB-funded sites in the audit control with AfDB-funded sites in the audit treatment allows us to directly estimate the effect of additional monitoring in a setting with low baseline monitoring and bundled contracting. Comparing WB-funded sites in the audit control with WB-funded sites in the audit treatment allows us to estimate the effect of enhanced monitoring in a setting with high monitoring and unbundled

[11] Treatment effects do not vary meaningfully by how many of a contractor's sites were audited (Table A20).

contracting. We combine estimates of the monitoring effect with estimates of the WB effect to back out the impact of unbundling. Specifically, we use the following regression specification:

$$y_i = \beta_0 + \beta_1 \mathrm{WB}_i + \beta_2 \mathrm{Treat}_i \cdot \mathrm{WB}_i + \beta_3 \mathrm{Treat}_i \cdot \mathrm{AfDB}_i + \mathbf{\Gamma} + \epsilon_i, \tag{2}$$

where WB_i and AfDB_i indicate whether site i is WB-funded or AfDB-funded. β_1 measures the impact of WB procedures among audit control sites. Treat_i indicates whether the site is an audit treatment site, such that β_2 and β_3 allow us to estimate the impact of enhanced monitoring among WB- and AfDB-funded sites, respectively. $\mathbf{\Gamma}$ is a vector of fixed effects (including constituency fixed effects) which vary somewhat across specifications as discussed below and in the table notes. Standard errors are clustered by site in all regressions except those run at the site level.

Assuming that the monitoring at WB-funded sites has the same impacts as our experimental monitoring, the effect of the WB's unbundled contracting can be recovered by subtracting the audit treatment effect among AfDB-funded sites from the aggregate WB–AfDB difference among audit control sites ($\beta_1 - \beta_3$). However, we interpret this calculation with some caution, as there are modest differences between the inspections Kenya Power implemented at WB-funded sites and the audits our research team conducted. We discuss this in more detail in Subsection 6.4.

5 Data

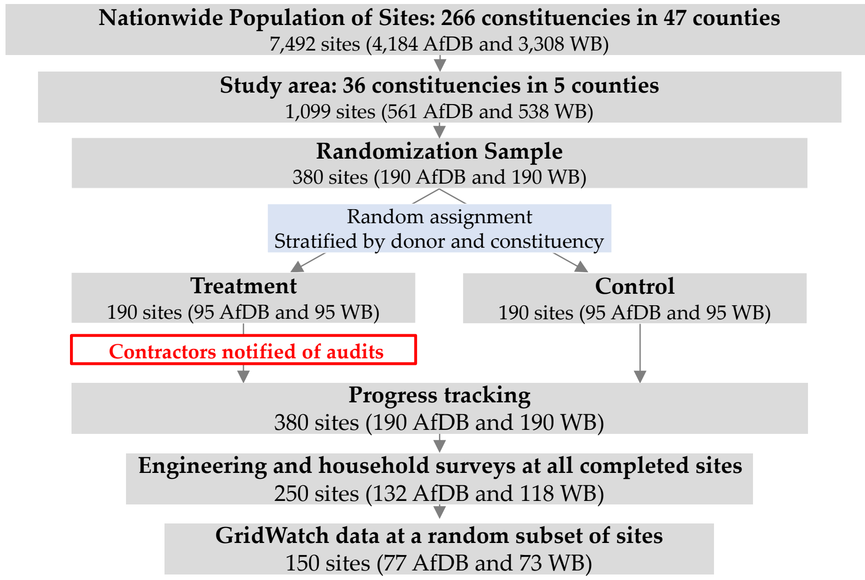
Enumerators employed by the research team conducted frequent short surveys—over the phone or in person—with village representatives at all 380 sites in the study sample to track construction progress, yielding a site-level panel dataset of construction progress. Reassuringly, nighttime radiance increases in the 12 months after the completion of household electricity metering (Figure A3), but not after the start of construction and stringing alone.

We conduct on-the-ground engineering assessments and socioeconomic surveys at all 250 sites where construction had made significant progress by the end of the main field activities in May 2021. There are nearly equal numbers of surveyed sites funded by both donors: 47% of the surveyed sites are WB-funded sites and 53% are AfDB-funded sites. Construction had not been completed—and usually not even begun—in the remaining 130 sites, limiting surveying activities there to the short progress assessments. We aimed to conduct the field surveys between six to twelve months after construction was reported to have begun at a site (although due to logistical constraints surveys were conducted a few months earlier or later in some cases). Figure 4 provides an overview of these study design elements.

5.1 Engineering assessments

The engineering surveys conducted at these 250 sites were developed in collaboration with recently retired Kenya Rural Electrification Authority engineers with expertise on the technical specifications of Kenya's electricity grid. Data collection consisted of two main parts. In the initial infrastructure census, enumerators recorded the locations of all poles in the low-voltage network, as well as their

Figure 4: Project design



Sample selection and randomization, starting with the nationwide sample of African Development Bank- and World Bank-funded sites selected for the Last Mile Connectivity Project. We randomly select 380 out of the 1,099 sites located in the five study counties and then randomly assign each of the 380 sites to control or treatment. Contractors were notified in 2017-2018 and assessments and surveys were carried out in 2018-2021. Engineering assessments and household surveys were completed at all 250 sites where there had been meaningful construction by the end of surveying activities in mid 2021. Construction progress tracking at the remaining sites continued through mid 2022.

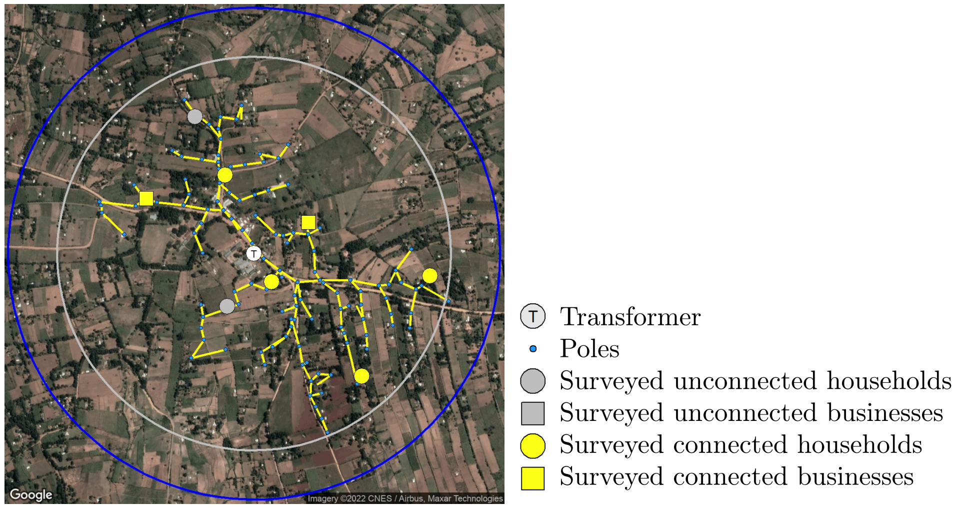
connectivity, up to 700 meters from the central transformer. Only households within 600 meters of the transformer were eligible for an LMCP connection: the 700 meter radius allows us to test whether construction was completed beyond the eligible region, for example in exchange for informal side payments from households. Enumerators also recorded the number of drop-down cables (connections between an electricity pole and a customer) connected to each pole, whether drop-down cables connected to a household or a firm, and any unconnected compounds located near the pole. This provides a measure of the total numbers of connected and unconnected households and firms at each site. Figure 5 displays network data recorded at an example site.[12]

In the second part of the engineering assessment, enumerators recorded characteristics of every pole and the conductors that connect them, focusing on outcomes most likely to affect grid quality and longevity. For instance, pole measurements included the angle relative to the ground (as tilting poles are more likely to fall), whether it was wood or concrete, whether it was firmly placed in the ground, whether it had a pole cap, whether it had any visible cracks, and whether it had the appropriate grounding wires, stay wires, and struts. For a random subset of poles, enumerators collected additional data on pole height, circumference, and characteristics of each strut or stay supporting that pole.[13] Measurements of conductors included whether it had appropriate clearance (from the

[12] If the network was too large to map in one day, enumerators would assess a random subset of branches. Scaling measured quantities up in proportion to the fraction of the grid surveyed yields an unbiased estimate of total quantities at that site. As an example, in the bottom right site shown in Figure A5 only the southern half of the site was surveyed. At 93% of sites at least 50% of the entire LV network was surveyed.

[13] At smaller sites, enumerators would conduct detailed measurements of every third or fourth pole, while at larger sites (of 120 or more poles) enumerators would conduct detailed measurements of every sixth pole.

Figure 5: Infrastructure data collected (example site)



Construction data collected at an example site (Figure A5 shows additional examples). The grey (blue) line denotes 600 (700) meters from the transformer. The engineering surveys record the locations of poles (blue dots), conductors (yellow lines), and infrastructure quality. At each site, between 4 to 9 connected and unconnected residential compounds and firms were randomly selected to participate in the socioeconomic survey (Subsection 5.2) and to receive GridWatch devices to measure power quality (Subsection 5.3): these are marked with yellow and gray circles and squares. (Note that random spatial noise has been added to preserve respondent anonymity here.)

ground, trees, brush, or structures) and whether any electric lines crossed. Measurements of drop-down cables included the distance between the pole and the customer's structure and whether the cable ended at a meter. Enumerators also noted whether it appeared to be an illegal connection, although this is very rare in the rural study setting (in contrast to some urban and peri-urban settings in Kenya and elsewhere). Finally, measurements of the transformer included whether the poles on which the transformer was mounted were leaning excessively, the number of missing or bypassed fuses, and whether the transformer had any other visible defects.

Overall construction quality is mixed in the study sample. About a quarter of surveyed poles had a large crack, and 47% of poles were missing a cap (Table A2 provides additional detail). At least one fuse was missing or had been bypassed in around a quarter of transformers surveyed: this could reduce transformer longevity as it is exposed to high-current events.

Of the 250 sites surveyed, 26 were located within 1,200 meters of each other (Figure A6 shows an example). This raises two potential concerns. First, poles or respondents located within 600 meters of two different surveyed transformers might be double counted. The survey methodology is robust to this potential source of error: LV networks in this area are constructed using a radial structure where no household is connected to more than one transformer. Second, if construction took place earlier at one transformer, then a neighboring transformer with later construction might require less expansion of the LV network to reach remaining households. Robustness checks show that the results reported below hold when dropping these sites (Subsection 6.6).

5.2 Household and firm survey data

After the infrastructure census, enumerators invited a random subset of connected and unconnected compounds and firms to complete a socioeconomic survey about the construction process, electricity connection quality and usage, their knowledge about future costs, experiences around safety and power reliability, and socioeconomic outcomes. The survey also asked about manual labor: anecdotally, households are occasionally asked to contribute manual labor to construction, for example, by digging their own holes for distribution poles, even though this is strictly against Kenya Power policy. Finally, informal field observations indicate that Kenya Power occasionally installs multiple meters within a single home compound, overstating the total number of households that are connected nationwide (perhaps in order to create inflated public perceptions of program progress). To disentangle this phenomenon from compound residents' genuine preference for having multiple electricity meters (for instance, if multiple separate households shared a residential compound), the survey asked not just how many meters were installed but also how many they had requested.

5.3 Power quality: outages and voltage

Improved construction quality could reduce power outages and increase reliability, which could have tangible benefits for household well-being and firm performance. To measure reliability and voltage we deployed the GridWatch technology (Klugman et al. 2021; Klugman et al. 2019) with a subset of surveyed households and firms. GridWatch measures minute-by-minute power state and voltage and can be installed by plugging a PowerWatch device (Figure A7) into a power outlet. We aggregate these high-frequency measurements to an hourly measure of average voltage and a daily measure of hours of electricity. We collected these data across 150 sites for two months each, staggered between June 2021 and June 2022, deploying four PowerWatch devices per site at a time.[14]

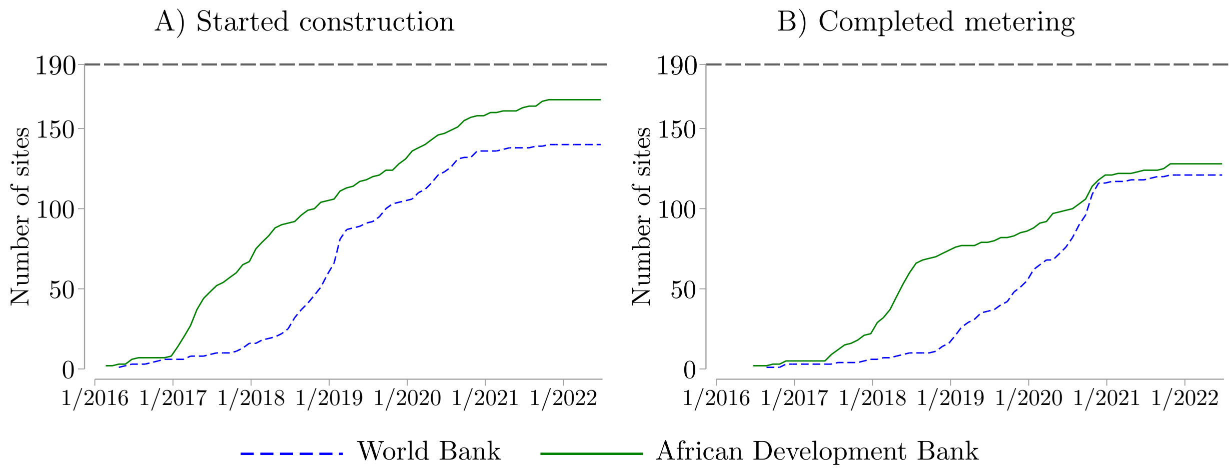
6 Results

Subsection 6.1 first documents patterns in construction delays. Subsection 6.2 then analyzes the quantity of construction. The next two subsections examine the quality of construction: Subsection 6.3 examines power outages and voltage quality, and Subsection 6.4 presents results that use the on-the-ground household and engineering assessments.

We identify three key patterns in the results that speak to the framework presented in Section 2. First, construction completion delays are significant at WB-funded sites, and are more modest but still meaningful at audit treatment sites. Second, WB-funded sites see a considerably higher quality of construction. Third, audit treatments improve the quality of construction along some dimensions at AfDB-funded sites but not at the WB-funded sites.

[14] The sample was reduced from 250 to 150 sites due to logistical challenges associated with the COVID-19 pandemic.

Figure 6: Construction progress by funding source



Data for 190 African Development Bank sites and 190 World Bank sites collected through phone surveys with village representatives. Figure A8 displays progress for pole installation and stringing. Figure A9 shows all four graphs by audit treatment status.

6.1 Construction timing and site completion

Of the 380 LMCP sites tracked by the survey team, 250 saw significant pole construction by the end of field surveying in May 2021. Construction varies significantly by funder: 70% of AfDB-funded sites saw construction whereas only 62% of WB-funded sites did, and this difference remains significant even when including constituency fixed effects. Sites with higher baseline nighttime radiance or with a higher land gradient (steeper sites) were less likely to be completed (Table A3). While WB-funded sites are on average steeper (Table 1), the primary outcome regressions presented below control for land gradient so these differences do not appear to be driving the findings.

Even conditional on completion, construction progress at WB-funded sites lagged significantly behind AfDB-funded sites. Panel A of Figure 6 demonstrates that this lag is driven by the initial delay in starting construction, likely driven by the ex ante administrative burden involved with contract unbundling. Construction at WB-funded sites started on average 10.2 months later than at AfDB-funded sites (Table A4): in mid-2018, as construction at WB-funded sites was just beginning, AfDB-funded sites reached 50% metering completion.[15] However, once construction started, it proceeded more quickly at WB- than at AfDB-funded sites, possibly because by that time all designs had been completed and materials supplied. The delay in stringing completion is therefore slightly less, at 9.5 months. However, the delay is then again exacerbated at the final household metering stage, at which the average lag is 16 months. Recall that the AfDB teams did not always inspect whether meters were functioning prior to issuing a JMC (Subsection 3.4). The more stringent WB inspection reports, which happened between stringing completion and metering activation, may explain why the delays were exacerbated at this final stage. Finally, all sites lagged significantly behind the initial contracting timelines: project appraisal documents for both AfDB-funded and

[15]The timeline in our study counties is thus in line with Kenya Power's own nationwide progress metrics, which reported that 49% of the AfDB household connections targeted had been achieved by mid-2018 (Kenya Power 2018a).

WB-funded sites originally planned for construction to be completed by early 2019.

The audit treatment caused some delays, but these are substantially smaller than the average delay at WB-funded sites: metering is completed on average 4.7 months later at audit treatment sites than at audit control sites. To isolate the impact of the unbundling directly, we estimate the impact of WB contracting and subtract the audit treatment effect ($\beta_1 - \beta_3$). This analysis indicates that unbundling per se caused a delay of 11 months ($p\text{-}val < 0.001$; see Table A4).

6.2 Quantity of construction

Household metering had been completed at 71% of both AfDB and WB-funded sites at the end of survey data collection in July 2022, more than five years after the start of contracting. At that point, a key remaining difference by funder was that construction had been only partially completed at 24% of AfDB-funded sites where construction had started, compared with only 14% of equivalent WB-funded sites. The large share of partially completed public projects in contexts with limited resources and administrative capacity is in line with previous evidence from low- and middle-income countries (Williams 2017; Rasul and Rogger 2018). If these sites are not eventually completed, it would signify that a substantial share of project spending was wasted on non-functional construction, with a substantially higher share in AfDB-funded sites.

Household access to electricity requires the construction of poles to carry electricity throughout the LV network, as well as customer connection cables to connect households to these LV wires. Table 3 shows that WB-funded sites saw fewer poles and fewer customer connections (the equivalent regression coefficients from Equation 2 are marked β_1, β_2, and β_3). There are on average 99 poles at AfDB-funded sites and 88 poles at WB-funded sites ($p\text{-}val = 0.055$), and on average 76 new LMCP customer connections at AfDB-funded sites and 61 at WB-funded sites ($p\text{-}val = 0.041$). There are several potential explanations for these differences, but one likely explanation is that installers at WB-funded sites might have been constrained by the quantity of materials that had earlier been purchased through the separate supply contracts, whereas bundled contractors (at AfDB-funded sites) could procure additional materials as needed during the installation phase.

Column (2) of Table 3 shows that the audit treatment increased the number of poles constructed at AfDB-funded sites but not at WB-funded sites. This indicates that unbundling contracts and monitoring may be substitutes, for example because bundled contractors (at AfDB-funded sites) had more discretion in changing site designs or supplies in response to the audit treatment, whereas installers at WB-funded sites were constrained by their assigned designs and previously procured supplies. Alternatively, the audit treatment may have had a limited impact at WB-funded sites due to the diminishing impact of enhanced inspections, above and beyond the additional inspections that Kenya Power had already carried out.

Columns (5) through (8) indicate that there was some construction between 600 to 700 meters from the transformer, despite the official guidelines indicating that construction was supposed to have extended only up to 600 meters.[16] WB-funded sites saw significantly less construction outside

[16]Kassem et al. (2022) find that 30% of LMCP households live more than 600 meters from the transformer. Our

Table 3: Connections and poles installed per site

	Entire site				Outside 600 meter boundary			
	Poles		Connections		Poles		Connections	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
β_1: World Bank (=1)	-11.9**	-2.2	-12.8**	-19.3*	-2.2***	-1.1	-1.4***	-0.9
	(5.9)	(10.1)	(6.2)	(10.7)	(0.7)	(1.1)	(0.5)	(0.9)
Treatment (=1)	6.3		4.9		-0.0		-0.1	
	(5.8)		(6.1)		(0.6)		(0.5)	
β_2: Treatment (WB sites)		-3.3		6.8		-0.7		-0.6
		(8.5)		(9.0)		(0.9)		(0.7)
β_3: Treatment (AfDB sites)		16.3*		2.8		0.8		0.6
		(8.3)		(8.8)		(0.9)		(0.7)
Observations	250	250	250	250	244	244	244	244
Control Mean	92.26	92.26	72.25	72.25	3.65	3.65	2.85	2.85
F-test $\beta_2 = \beta_3$ (p-val)		0.10		0.75		0.24		0.24

β_1, β_2, and β_3 are estimated as per Equation 2. All regressions include constituency fixed effects. Standard errors shown in parentheses. The sample size in columns 5–8 is slightly lower due to field logistical complications. We calculate the quantities of poles and connections at these sites using the engineering survey, but since we do not have their GPS coordinates, we exclude them from columns 5–8. $^* \leq 0.10, ^{**} \leq .05, ^{***} \leq .01$.

the boundary, possibly due to more stringent adherence to official LMCP rules. This could be viewed as a positive outcome (especially if some of these connections are made in exchange for bribes), but does contribute to fewer connections per site. That said, the household survey data indicate similar rates of requests for informal side payments—at approximately 8%—for households and firms inside versus outside the 600 meter boundary. Voltage decreases with distance from the transformer, as expected, but this decrease is not correlated with the funder (Subsection D.9).

We estimate $\beta_1 - \beta_3$, the impact of WB contracting minus the additional audit treatment, to isolate the impact of contract unbundling directly, as distinct from the WB's enhanced monitoring activities. Using this method, unbundling decreased the number of poles by 18.5 ($p\text{-}val = 0.06$) and the number of connections by 22 ($p\text{-}val = 0.04$). We interpret these numbers with some caution, as the inspection reports that Kenya Power completed at WB-funded sites differed from the audit treatment in some nuanced but important ways (as we discuss in Subsection 6.4 below), and thus they may not be fully equivalent.

Despite the LMCP mandate to connect all households and firms within 600 meters of the transformer, 10% of households in each village where construction was completed did not have a physical electricity connection.[17] Several factors likely contributed to this. Among both WB- and AfDB-funded sites, 30% of unconnected households noted that they were absent on the day on which Kenya Power enrolled households or when construction happened. 22% of households who did not get connected reported the key barrier as up-front costs: 16% name internal wiring costs and 9% of connected households report having been asked to pay a bribe). This is noteworthy because,

numbers may be lower because enumerators only surveyed households and firms out to 700 meters and not beyond.

[17] Furthermore, approximately 13% of households with a physical electricity connection have never seen electricity actually flow through this connection.

Table 4: Donor and audit impacts on power and voltage

	Hours of power		Average voltage	
	(1)	(2)	(3)	(4)
World Bank (=1)	-0.19	-0.31	1.72	2.86
	(0.21)	(0.22)	(2.34)	(2.72)
Treatment for WB Sites	-0.00	0.33*	3.46	1.40
	(0.24)	(0.17)	(2.22)	(1.77)
Treatment for AfDB Sites	-0.15	0.10	4.35**	4.95*
	(0.18)	(0.18)	(2.01)	(2.59)
Observations	9906	9906	654541	645655
Fixed effects	No	Yes	No	Yes
Control Mean	23.10	23.10	232.63	232.63
F-test $\beta_2 = \beta_3$ (p-val)	0.63	0.42	0.77	0.25

Columns (1) and (2) display daily hours of power per site. Columns (3) and (4) display hourly voltage per respondent. Nominal voltage in Kenya is 240V. Column (2) contains week of sample by constituency fixed effects (interacted) and Column (4) contains day of sample by hour of day by constituency fixed effects (all interacted). β_1, β_2, and β_3 are estimated as per Equation 2. Power quality is measured using GridWatch devices. $^* \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

according to LMCP media information campaigns during this period, there was not supposed to be any up-front cost (Kenya Power 2016a): ready boards were supposed to have been made available to households who were unable to pay the upfront wiring costs, and of course bribes are illegal.

6.3 Power outages and voltage quality

The GridWatch devices recorded an average of 61 minutes of power outage per day, a substantial amount. Users also experience poor voltage quality: Kenya's nominal voltage is 240V, but voltage in the audit control group is on average only 233V.[18] This could affect day-to-day appliance use and damage appliances in the long run.

Table 4 suggests that WB procedures did not cause statistically or economically meaningful reductions in power outages or improvements in voltage quality over the time period we study. The results are similar when estimating daily or monthly coefficients (Figure A10).

The audit treatment had no measurable impacts on power outages or voltage at WB-funded sites. However, audits had a statistically and economically meaningful effect on voltage quality at AfDB-funded sites: those that received the audit treatment experienced average voltage of 238V, significantly closer to nominal voltage of 240V than the control mean of 233V. While we cannot reject $\beta_2 = \beta_3$, taking this suggestive evidence together with the results in Subsection 6.2 (and with the results on engineering and socioeconomic outcomes discussed below) speaks to the substitutability of contract unbundling and enhanced monitoring in this context.

6.4 Engineering assessment and survey results

While the data just presented showed that WB procedures had no detectable impact on electricity quality, they appear to have improved construction quality in ways that could generate long-term

[18]In some contexts, average voltage as a metric might hide spikes and sags. In Kenya, however, the data indicate that when households experience poor voltage, it is almost exclusively low voltage.

Table 5: Primary engineering and socioeconomic outcomes

	(1) WB Effect Estimate (β_1)	(2) Audit Treatment Effect, WB Sites (β_2)	(3) Audit Treatment Effect, AfDB Sites (β_3)	(4) N
Outcome 1: Construction quality index	0.64***	0.10	-0.03	250
	(0.21)	(0.20)	(0.18)	
Outcome 2: Network size and configuration index	-0.04	0.19	-0.08	244
	(0.16)	(0.16)	(0.18)	
Outcome 3: Construction timing index	-0.90***	-0.07	-0.29*	250
	(0.17)	(0.16)	(0.17)	
Outcome 4: Household installation quality index	0.05	0.02	0.23*	944
	(0.12)	(0.11)	(0.12)	
Outcome 5: Household cost, experience, bribery index	0.13	0.05	0.11	944
	(0.12)	(0.11)	(0.10)	
Outcome 6: Reliability and safety index	-0.11	0.03	-0.01	944
	(0.13)	(0.14)	(0.11)	
Outcome 7: Knowledge index	0.14	-0.00	0.07	944
	(0.10)	(0.09)	(0.10)	
Outcome 8: Electricity Usage index	0.12	0.11	0.28**	944
	(0.13)	(0.10)	(0.13)	

Each row presents coefficient estimates from a separate regression. Outcome variables are indices constructed from groups of variables standardized to have mean 0 and standard deviation 1. β_1, β_2, and β_3 are estimated as per Equation 2. Column (1) displays the impact of World Bank (WB) funding relative to African Development Bank (AfDB) funding. Columns (2) and (3) display the audit treatment effect among WB- and AfDB-funded sites, respectively. In rows 1–3, observations are sites. In rows 4–8, observations are occupants of connected compounds. All regressions control for site land gradient and public facility type (given some baseline imbalance along these dimensions) and include constituency fixed effects. Standard errors are clustered by site and shown in parentheses. Table A5 reports the version with interaction terms. $^* \leq 0.10, ^{**} \leq .05, ^{***} \leq .01$. The sub-components for each index are presented in Table A6 through Table A12. Table A13 through Table A15 present results on additional secondary outcomes specified in the pre-analysis plan (Berkouwer et al. 2019).

benefits. Table 5 presents results using primary outcome indices pre-specified in the pre-analysis plan (Berkouwer et al. 2019). Outcomes 1–3 use site-level observations (largely from the engineering assessments) while outcomes 4–8 use respondent-level observations (largely from the household and firm surveys). All indices are standardized to have a mean of zero and a standard deviation of one.

In one of the central results of this study, Column (1) of Table 5 (β_1) shows that overall construction quality (Outcome 1) was on average 0.64 standard deviations higher at WB-funded sites. This is driven by increased presence of pole caps, struts, and stays on poles at WB-funded sites (Table A6): recall that these are the technical components emphasized in the WB inspection reports. While Subsection 6.3 shows that these features apparently had limited impacts on power quality over the five years we observe, they can reasonably be expected to increase the lifetime of the poles—and thus the entire local LV network—over the long-term. Engineering research suggests that capped poles generally experience inner-pole moisture levels between 8–20% whereas uncapped poles experience levels between 30–80%, well above the threshold of 28–30% "considered necessary for fungal attack" (UPRC 2018).

Columns (2) and (3) of Table 5 estimate the audit treatment effect among WB- and AfDB-funded sites, respectively (β_2 and β_3). The estimate in Column (3) corresponds to the impact of enhanced monitoring among sites with bundled contracts. Additional audits did not affect outcomes at WB-funded sites. However, they did increase household installation quality among AfDB-funded sites (Outcome 4), driven by earlier meter activation and higher likelihood of having a working meter (Table A8). This substitutability is in line with the extensive margin effects discussed in Subsection 6.2 and the positive impact on voltage quality result presented in Subsection 5.3. The improvements in voltage quality and household installation quality likely contributed to the increase in household electricity access and usage estimated here (Outcome 8; Table A12). Outcomes 5, 6, and 7 (household cost and experience; reliability and safety; and knowledge) show little difference across WB- and AfDB-funded sites or due to the audit treatment (Table A9, Table A10, Table A11).

To isolate the impact of contract unbundling, we estimate the impact of WB contracting minus the audit treatment effect ($\beta_1 - \beta_3$). This yields an increase of 0.67 standard deviations (*p-val* = 0.001) on the construction quality index and a –0.61 effect (*p-val* $<$ 0.001) on the timing index. This suggests that unbundling contracts has substantial impacts on multiple important project outcomes. However, we interpret this result with some caution, as the audit treatment differed somewhat from the WB inspection reports. For example, the inspection reports (described in Subsection 3.4) investigated more technical components of LV network construction (such as pole quality) whereas the audit treatment (described in Subsection 4.2) also emphasized the quality of household connections. This could explain why WB procedures affected core engineering components (Outcome 1) whereas the audit treatment at AfDB-funded sites primarily improved household installation quality (Outcomes 4 and 8), and why WB procedures did not have an impact on voltage quality while the audit treatment did improve voltage quality at AfDB-funded sites (Subsection 6.3).

In some contexts, bundling might incentivize excessively frugal designs such that the installing firm can save on supply and installation costs. In our context, this would show up as a lower number of poles in the designs. We do not find evidence of this in the aggregate (Outcome 2 of Table 5) or looking at specific design features individually (Table A7).

6.5 Discussion in the context of the theoretical framework

The results presented above follow the model implications outlined in Section 2. Combining unbundling and high monitoring generates unambiguously higher construction quality but incur additional delays (as observed by comparing WB-funded sites and AfDB-funded sites). From a benchmark of bundling and low monitoring, enhancing monitoring generates sizeable quality improvements, even though unbundling generates significantly higher costs and delays. Speculatively, under bundled contracting, installers can respond more effectively to the specific incentives generated by the additional inspections. Given that the additional inspections implemented by Kenya Power targeted slightly different dimensions than those implemented by our research team (theirs focused more on construction whereas ours focused more on household connections), this is consistent with the fact that the quality improvement comes through in the construction quality index for WB-funded sites but the household installation index for treated AfDB-funded sites. These modest on-the-ground differences can explain why the quality levels achieved are not identical (as was predicted in the conceptual framework).

As noted above, the fact that the audit effects were limited at WB-funded sites could be due to two distinct reasons. First, this could be because unbundling and monitoring are substitutes rather than complements, and the WB procurement approach already includes unbundling. Second, it could be due to the diminishing marginal benefits of increased monitoring, since the WB already mandated an additional layer of inspections beyond that used at AfDB-funded sites.

6.6 Robustness

We conduct numerous robustness tests to confirm these results (Subsection D.7). All results in Table 5 control for land gradient and facility type, but not doing so does not qualitatively affect the results. Construction outcomes are generally not correlated with land gradient (Table A16 and Figure A11) or with facility type (Table A1, Table A17, and Table A16). We also explore heterogeneity in the time between construction and power measurement (Subsection D.9), omit an ambiguous ready board question in the survey (Table A8), exclude one particular contractor that experienced unusual financial circumstances and a legal case[19] (Table A18), and drop sites that are located within 1,200 meters of another site (Table A19). None of these adjustments qualitatively affects the results described above.

7 Cost effectiveness

The improvement in overall construction quality at WB-funded sites—combining unbundled contracting and enhanced monitoring—at the cost of delays is a central finding of this study. This section examines the WB contracting structure's impacts on costs and cost effectiveness. One argument in favor of contract unbundling in this context (given to us informally by WB officials) is that it could generate cost efficiencies, specifically in that pooling the procurement of materials would generate purchaser market power that could lead to cost savings. Subsection 7.1 therefore investigates program costs, and Subsection 7.2 then investigates the trade-off between the costs of short-term construction delays versus the potential long-term benefits from greater infrastructure resilience, based on the framework from Equation 1 presented in Section 2.

7.1 Cost analysis

Kenya Power awarded $154 million in contracts for AfDB-funded sites and $133 million in contracts for WB-funded sites.[20] Table 6 presents project costs by donor. 5,320 AfDB-funded sites and

[19]See *AEE Power SA v Kenya Power & Lighting Company Ltd* (2020).

[20]This excludes a $2.0 million contract awarded for the procurement of 1,000 new WB transformers. Since these 1,000 sites received similar shares of the remaining contracts, we include these sites in the aggregate cost calculations, accounting for the fact that they were designed to have approximately 21% more new household connections.

Table 6: Site, connection, and materials costs by donor

		African Development Bank	World Bank	Percent Difference
(1)	Sites planned	5,320	4,200	–21%
(2)	Sites completed	3,800	3,000	–21%
(3)	New household connections per site	72	58	–19%
(4)	Contract amount per site completed	40,513	42,249	+4%
(5)	Contract amount per household connection	563	728	+30%
(6)	Contract amount per wooden pole	159	99	–38%
(7)	Contract amount per concrete pole	240	199	–17%

Aggregate connection and pole procurement quantities and costs, per the contracts signed between Kenya Power and contractors under World Bank and African Development Bank funding tranches.

3,200 WB-funded sites had originally been slated for maximization, but only 71% of LMCP sites actually saw construction, according to survey data and conversations with Kenya Power personnel. The survey team identified on average 72 new LMCP household connections at AfDB-funded sites and 58 at WB-funded sites, implying that the average cost per household connection is \$563 for contracts for AfDB-funded sites while it is \$728—30% higher—for contracts for WB-funded sites.[21] Furthermore, these cost estimates exclude any additional Kenya Power staff labor hours associated with the WB's administrative and monitoring costs (i.e., in setting up additional contracts and bidding processes, etc.), which could exacerbate this cost difference. In sum, it does not appear that the WB was able to carry out lower-cost projects overall: in line with the model, contract unbundling increased average costs per connection in this setting.

These cost estimates are slightly lower than the \$739 average total cost per connection that Lee et al. (2020) estimate under a 100% electrification scenario in rural Kenya using data collected in 2014. The difference can be reasonably attributed to implementation efficiencies derived from nationwide coordination and general learning about rural electrification construction since 2014. In line with Lee et al. (2020), the observed costs exceed the value of rural electrification as measured through simulated willingness-to-pay (\$293) and revealed preference (\$147) approaches.

Taken at face value, the cost per pole enumerated in rows (6) and (7) of Table 6 would suggest that WB-funded contracts did secure poles more cheaply than AfDB-funded contracts. However, the contract amounts listed in bundled contracts may not reflect true procurement costs: our conversations with implementation contractors suggested that they sometimes shift labor costs onto materials on paper, as these invoices are paid sooner, generating additional liquidity. In contrast to the case of unbundled contracting, where the principal can observe each component's purchase cost, these practices are not observable to the principal when they are based on subcontractor relationships. This is an example of the opacity that bundled contracting can create for the principal.

As another example of gaps between reporting to the principal and on-the-ground measure-

[21] The average cost per connection would have been \$687 at AfDB-funded sites and \$571 at WB-funded sites when using Kenya Power's initial public targets of on average 59 new connections at AfDB-funded sites and 74 at WB-funded sites (Kenya Power 2016a). Assuming 80 new connections at all sites would yield a construction cost of approximately \$506 per household connection at AfDB-funded sites and a nearly identical \$528 at WB-funded sites.

ments, there appear to be disparities between contracted and built quantities. According to the procurement contracts, 18% of poles at WB-funded sites and 50% of poles at AfDB-funded sites were concrete—however, according to our on-the-ground surveys of all poles in our sample sites, only 3% of poles at WB-funded sites and 25% of poles at AfDB-funded sites were concrete.[22]

7.2 Cost-benefit analysis

The 30% higher cost per electricity connection for contracts funded by the WB documented above might be worth it if the gains in construction quality are sufficiently large. We thus next evaluate the gains in quality against the cost per connection and the estimated impacts of construction delays on welfare to shed light on the key conceptual trade-off represented by Equation 1 in Section 2.

AfDB-funded sites reached construction milestones 8 to 16 months earlier than WB-funded sites on average, increasing the net present value of new connections. WB-funded sites saw improved pole and pole installation quality, potentially increasing pole longevity by an estimated 5–15 years and reducing long-term repair and replacement costs for Kenya Power (UPRC 2018). We also factor in that only 71% of sites were completed, and assume that households discount delayed electricity access at a 10% annual discount rate while the social planner discounts future maintenance costs at 5% per year (Figure A12 presents alternative scenarios). This analysis focuses on audit control sites to avoid confounding these differences with the audit treatment's heterogeneous impacts; we separately assess the costs and benefits of the audit treatment below.

Figure 7 presents the results in two panels to emphasize the role of one important attribute. Panel A supposes that WB- and AfDB-funded sites both benefit from 80 new household connections. Panel B reflects our count of LMCP household connections on the ground, which average 72 at AfDB-funded sites and 58 at WB-funded sites among audit control sites. These additional connections sway the net benefits calculations heavily in favor of AfDB procedures.

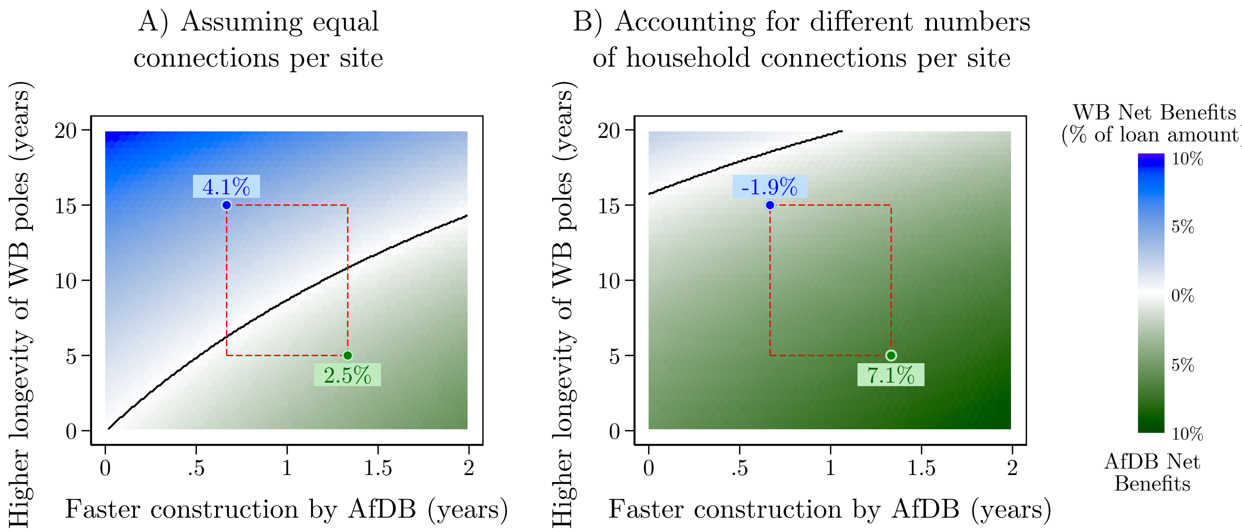
To illustrate the uncertainty in these estimates, the red box marks a range of 8 to 16 months faster construction and between 5 to 15 years of additional service life for poles, consistent with the data and with Muthike and Ali (2021). Using plausible estimates of the gains in construction speed and in quality of poles, the overall net benefits of either set of procurement policies are ambiguous, ranging anywhere from WB procedures having a net benefit worth 4% of total project costs to AfDB procedures having a net benefit worth 7% of project costs. (Figure A12 displays qualitatively similar results under a range of alternative assumptions.)

Under a shorter time horizon, or if the value of a connection to households were larger, the relative benefits of AfDB contracting would be more pronounced, up to 16% of the total. Under a lower discount rate the relative benefits of WB contracting would be more pronounced, up to 5% of the total. However, it appears unlikely that WB procurement procedures would have generated the 30% improvement required to make up for the increased costs per connection.[23]

[22] We interpret this result with some caution since we cannot distinguish existing poles from poles those constructed during LMCP. If pre-existing poles were disproportionately wood poles then this could explain part of this discrepancy.

[23] This result holds across a fairly broad range of assumptions. Even uniformly assuming 80 households and 112 poles per site for both funders, and assuming only 8 months of delay and 15 years of improved pole longevity, with

Figure 7: Costs versus benefits of different contracting approaches



Households are assumed to value a connection at $147 (Lee et al. 2020) and have an annual discount rate of 10%. The social planner is assumed to have a 20-year time horizon and an annual discount rate of 5%. The horizontal axis represents the gains from households benefiting sooner. The vertical axis represents improved grid quality, assumed to accrue to the expected service life of poles with a constant annual probability of pole failure. The red box marks 8–16 months faster construction (consistent with the results above) and 5–15 years improved service life for poles (following Muthike and Ali 2021). Panel A assumes 80 new household connections per site at all sites. Panel B reflects our count of household connections on the ground, which average 72 at African Development Bank-funded sites and 58 at World Bank-funded sites. Figure A12 explores additional assumptions.

Section 6 showed that the additional audits improved some household installation outcomes at AfDB-funded sites. The audits were conducted at an average cost of approximately $500 per site (around 1.2% of the average LMCP cost per site). While the audit treatment did not increase the number of drop-down cables (Table 3), electricity actually flowed through those connections for approximately 8% more households, and the audit treatment increased the fraction of households with a working meter by 11% (Table 5, detailed in Table A8). Valuing each additional working connection conservatively at $147, the implied added value of $1,029 far exceeds the cost of the audit treatment. This is despite the fact that the audit treatment activity was more involved and thus more expensive than would be needed in other contexts as they also included household and firm surveys, which are not part of the standard inspection reports (IRs) conducted at WB-funded sites. These results are consistent with the framework presented in Section 2: bundled contracts with high levels of monitoring may successfully incentivize the selection of high quality firms and higher effort, with fewer delays and administrative costs as compared with unbundled contracts.

These results come with important caveats. The cost calculations do not consider the additional staff time incurred by Kenya Power, the WB, and other government agencies due to increased paperwork and processing necessary to implement WB contracting procedures. The benefit calculations also do not consider spillovers such as increased knowledge of oversight mechanisms among Kenyan government agencies, which could positively affect other programs. We also do not consider

a 40 year time horizon and 5% discount rates (all favoring WB), WB net benefits add up to 5.4% of the loan.

possible degradation of electricity service quality and reliability over time due to lower quality construction. Perhaps most importantly, we do not directly observe the leakage of funds. It is possible that WB contracting requirements meaningfully reduced leakage, which was recently observed to be substantial for WB lending (e.g. Andersen et al. 2022). However, to the extent that WB procedures increased the availability of funds for intended construction by reducing leakage, this does not appear to have increased the number of household connections.

7.3 Policy discussion

While the exercise conducted above focuses on rural residential electrification in Kenya, the calculations may also illustrate the trade-offs that influence the relative benefits of different procurement contracting approaches for large-scale infrastructure projects more generally. If the planner discounts future costs and benefits more severely, if benefits are larger, or if unbundling will produce greater delays, then bundling contracts may be more attractive. Conversely, if bundling is expected to cause a greater decline in quality—perhaps because there are many low quality local firms bidding for projects—unbundled contracting may yield higher net benefits. In some settings, a combination of bundled contracting with enhanced monitoring may generate quality improvements with less delay or administrative cost than unbundling.

Next, to deepen understanding of the key processes, we complement the empirical results with qualitative data gathered during interviews with officials at Kenya Power, the WB, and the AfDB over several years.[24] Kenya Power's administrative burden under unbundling was significantly higher than under bundled contracting. The greater absolute number of contracts and the substantial heterogeneity in legal details across different types of contracts required more Kenya Power staff time to write, issue, review, and award bids. Contracting between the principal and the designers and suppliers was significantly more involved (requiring official tender and bid review processes) than the subcontracting processes used by AfDB installers for those same goods and services. Despite these substantial differences in staffing demands across the two donors, total Kenya Power staff time availability was equal across the WB and AfDB components (one full-time staff member each), and the employees who held these positions were all certified electrical engineers with similar skill and education levels (at least a bachelor's degree in electrical engineering). It is possible that increasing Kenya Power staff time for the unbundled WB contracts might have moderated some of the delay caused by unbundling, though at the expense of incurring additional administrative costs.

Unbundled contracting also created coordination frictions, exacerbating administrative costs and delays. The lack of coordination between the design and installation contracts meant that designs were sometimes out of date by the time construction began, requiring costly adjustments to the designs or the procurement of additional materials. Similarly, a lack of coordination between materials and installation contracts meant that materials were often physically transported into Kenya Power custody before installers were ready, accruing expensive storage fees. These coordination frictions

[24] Appendix E provides an anonymized list of individuals with different project roles and responsibilities that our research team interviewed for this research.

were substantially lower for bundled contracts, where installers could more easily adjust designs or acquire additional supplies at their discretion.

In interviews, we learned that one of the WB's reasons for choosing unbundled contracting was the belief that having coordinated nationwide contracts for major materials purchases would enable them to secure lower prices through auction. This turns out to have been true on paper: the cost per wooden and per concrete pole was 38% and 17% lower, respectively, in the WB contracts when compared with the AfDB contracts. However, as noted in Subsection 7.1 above, the aggregate costs per site and per successful connection are in fact substantially higher at WB-funded sites.

One channel through which unbundling may have operated is through the selection of higher-type firms. The selection process for subcontractors by installers featured significantly less oversight than Kenya Power's official auctions. We investigate whether these different selection mechanisms led to differences in provider selection. Twenty-one companies were directly awarded at least one unbundled supplier contract and 29 companies were listed as a subcontractor for an AfDB-funded installer.[25] In addition to the winning bids, 185 competing bids for WB-funded supplier contracts were considered eligible. We focus on poles, cables, and conductors, which were procured through competitive auctions for unbundled WB-funded contracts but subcontracted out by AfDB-funded installers.

Firm types do not appear to differ substantially across the two contracting structures at least along basic characteristics; we of course cannot directly measure underlying firm quality (the theoretically relevant quantity). First, there is considerable direct overlap in the firms themselves: seven of 21 WB-funded contractors were also selected as subcontractors by AfDB-funded installers, and over half of the AfDB-funded subcontractors (15 out of the 29) appear on the bidder list, indicating that many firms actively sought to be funded by both donors. Second, while there is limited information available about these design and supply firms, the providers selected under AfDB and WB regulations appear to be similar along several observed dimensions. Approximately two-thirds of (sub)contractors were from Kenya, 10% were from China, and 10% were from India (Figure A13), and these proportions are similar for those awarded contracts with either WB or AfDB. 48% of WB contractors and 22% of AfDB subcontractors had also been awarded at least one other WB procurement contract prior to the start of the LMCP. Unfortunately, there is limited other information about the management and histories of these contractors.

8 Conclusion

Outsourcing public goods provision creates a standard misaligned incentives problem: how can a principal identify good contractors and incentivize them to provide high quality projects? Public procurement regulations can have important implications for the costs, timeliness, and quality of infrastructure construction, a major spending category for governments and aid donors. One key

[25] Implementing firms were not required to comprehensively disclose subcontractor relationships, but only to get approval to use a certain subcontractor. In many cases the installer obtained approval for multiple contractors, and did not disclose which subcontractor they eventually opted to contract with.

decision the principal faces is whether to unbundle the various components of a project across contracts auctioned to private firms, or whether to award a single bundled contract that includes multiple components. This decision is ubiquitous in public contracting, but causal inference on this topic has been hampered by the infrequency, endogeneity, and complexity of infrastructure projects.

We present a stylized framework to provide intuition for this problem: unbundling can improve outcomes by enforcing more stringent eligibility criteria on subcontractors, but may introduce additional delays and inefficiencies. Furthermore, combining bundled contracting with high monitoring can achieve similar quality standards but with significantly fewer administrative costs and delays, because it leverages bundled contractors' private information about potential subcontractors while still exploiting the synergies inherent in contract bundling.

We then use natural policy and experimental variation to study these questions in the context of the Last Mile Connectivity Project (LMCP), one of Kenya's largest public infrastructure construction projects. A key feature of the program is the arbitrary assignment of contracting requirements across neighboring villages to different funders within the same government program. To disentangle the impacts of contract unbundling and enhanced monitoring we implement an additional randomized audit treatment at a subset of sites.

We find that WB-funded sites experience significant delays in project implementation, with households receiving electricity on average 16 months later than households in AfDB-funded sites. Yet there is a stark trade-off: we estimate a 0.6 standard deviation improvement in construction quality at WB-funded sites, driven by increased presence of pole caps, stays, and struts, which were key components examined during the additional inspection round required under WB procedures, and which can have long-term impacts on the longevity of the local infrastructure network.

The audits generate a 0.2 standard deviation improvement in household installation quality and a 0.3 standard deviation improvement in electricity usage at AfDB-funded sites, while causing significantly shorter delays than those caused by unbundled contracting sites. The enhanced monitoring has no impact at WB-funded sites, most likely due to the substitutability of monitoring and unbundling, or because additional monitoring has a decreasing marginal effect.

Comparing the procurement processes in this context may generate insights for a trade-off relevant to a wider range of infrastructure projects. The policymaker may need to weigh the short-term benefits of achieving earlier project completion (the AfDB-funded approach in this context) versus the longer-term benefits arising from improved project quality (under the WB-funded approach), according to their time preferences. We evaluate this trade-off under a plausible range of assumptions and find that neither approach definitively dominates the other in this context: the results imply anything from a net benefit of 7% of project value in favor of the AfDB approach to a net benefit of 4% of project value in favor of the WB approach.

In this context, enhanced monitoring appears to be an effective and lower-cost substitute for contract unbundling, achieving significant improvements in construction quality without the delays. Furthermore, unbundling contracts greatly increases the principal's administrative burden, which—in contexts where staff time and human capital are constrained—can generate substantial delays. Taken together, these results suggest that combining bundled contracting with more rigorous monitoring could reduce delays while maintaining construction quality standards.

Several important limitations are worth noting. First, the more stringent WB procurement conditions could generate additional longer term benefits that are hard to measure, including improved institutional capacity or accounting practices in Kenya public sector organizations. Second, while we carry out data collection up to five years after construction, some of the outcomes of interest may only emerge after longer time horizons, including possible differences between WB-funded and AfDB-funded sites in terms of the longevity of the local grid network and the reliability of power experienced by households, with gains in WB-funded sites potentially growing over time. Finally, Kenya is a relatively high-capacity state compared to its East African neighbors, and its internal regulatory system may be sufficiently rigorous so as not to benefit meaningfully from the additional WB procurement requirements. It is possible that the results would not hold in a setting with weaker institutional capacity, like some of its regional neighbors (as argued for instance by Bosio et al. 2022). Additional research is needed to understand the potentially heterogeneous impacts of procurement processes over time and in other settings.

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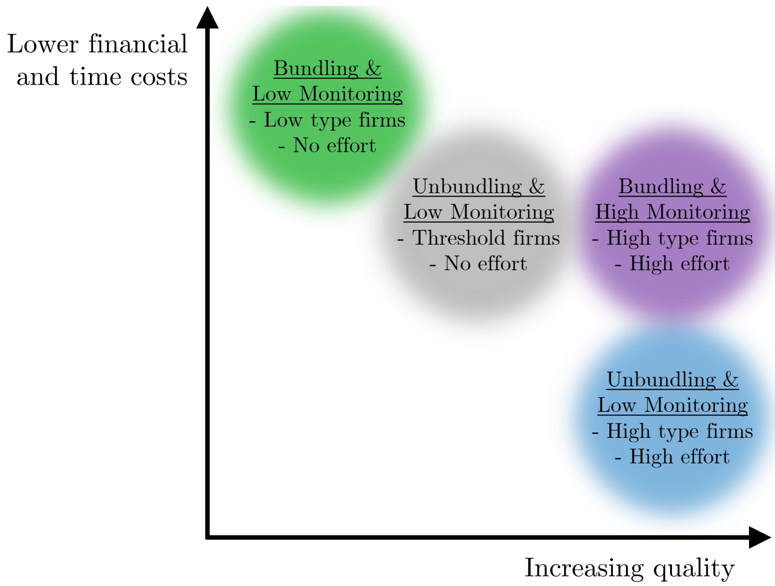
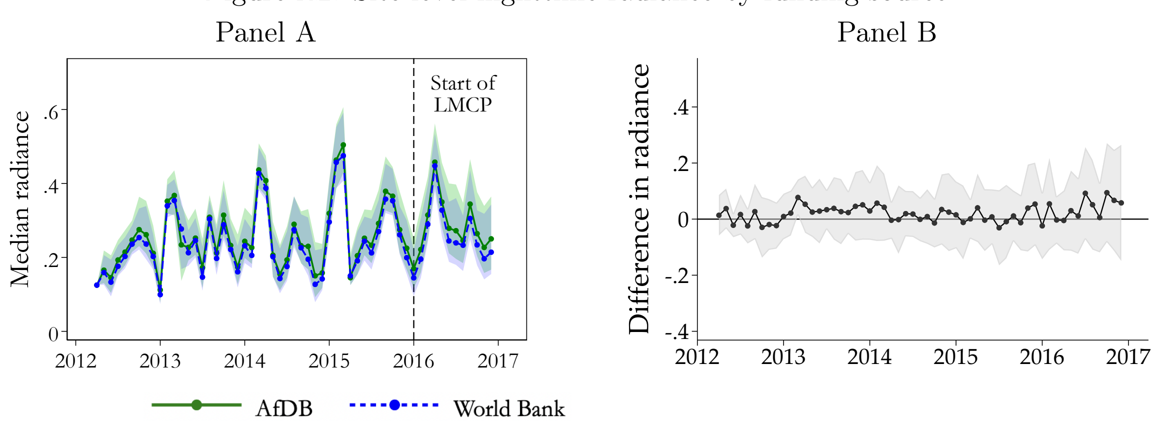
A Appendix Figures

Figure A1: Schematic of monitoring and bundling structures



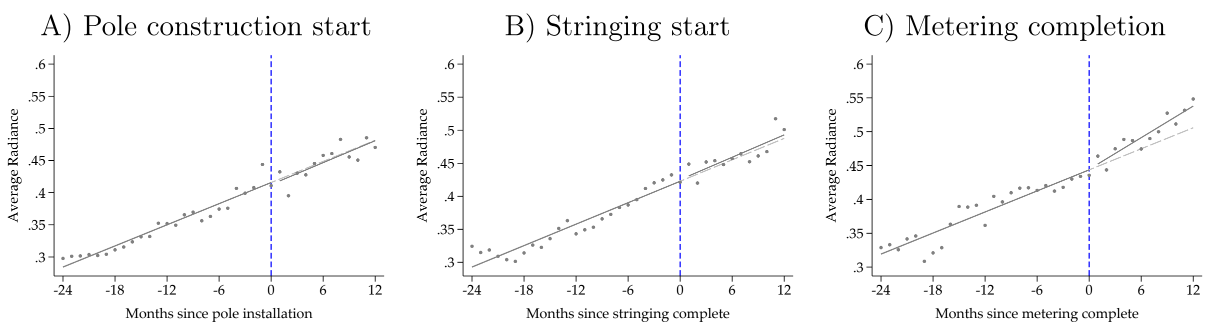
A graphical representation of how different monitoring levels (low or high) and contracting structures (unbundled or bundled components) affect project quality and costs through the lens of the framework presented in Section 2. The project's aggregate net benefits generally increase as financial and time costs decrease and quality increases, but the exact indifference curves depend on how the principal values cost and timeliness vis-a-vis quality, which is determined by, for example, their intertemporal discount rate. The green area (top left) approximates the structure used by the African Development Bank for the LMCP in Kenya. The blue area (bottom right) approximates the structure used by the World Bank for the LMCP in Kenya. The model suggests that combining bundled contracts with high monitoring can generate similar quality as unbundled contracting but with significantly fewer delays and administrative costs. The purple area (middle right) approximates this structure, which we empirically evaluate this using a randomized audits experiment. The gray area is unobserved in our context; placement reflects the model's predictions.

Figure A2: Site-level nighttime radiance by funding source



Panel A presents median monthly nighttime radiance from the Visible Infrared Imaging Radiometer Suite (VIIRS) between 2012-2017 per month, with bands showing the 25th to 75th percentile across sites, before and after the start of the Last Mile Connectivity Project (LMCP). Panel B confirms that radiance is statistically indistinguishable across World Bank and African Development Bank-funded sites (estimates include constituency fixed effects). Table 1 confirms baseline balance using a pooled regression of these data.

Figure A3: Event study: nightlights after construction progress



Data on construction progress collected through phone surveys with local village representatives. As expected, nighttime radiance data (Elvidge et al. 2017) increases after metering completion (when the electricity connection is activated) but not earlier.

Figure A4: Monitoring Intervention

THE WORLD BANK
IBRD • IDA

Kenya Power

Contractor XYZ
ADDRESS
P.O. Box YYY-ZZZ
Nairobi, Kenya

June 2017

TO: CONTRACTOR NAME
RE: ENHANCED MONITORING PROGRAM ("EMP") FOR LMCP MAXIMIZATION SITES

Dear Sir/Madame:

Kenya Power aims to provide the highest quality of electricity to all Kenyans. To achieve this goal, an international team of engineers will closely audit the quality of construction at a number of Last Mile Connectivity Project ("LMCP") maximization sites. These independent audits will be performed as part of the Enhanced Monitoring Program ("EMP"), and will target both African Development Bank and World Bank project sites. The results of the EMP audits will be shared with project supervisors, financiers, and international agencies, all of which may impose consequences on future contracting opportunities, as they see fit.

Upon project completion, EMP technicians will extensively measure the quality of various aspects of construction, including:

- Distance between poles
- Line sag
- Quality of connection between transformer and LV wiring
- Blackouts and electricity reliability post-connection

We wish to inform you of the sites that have been awarded to you that have been selected for the EMP. Please find attached a list of these sites.

Sincerely yours,

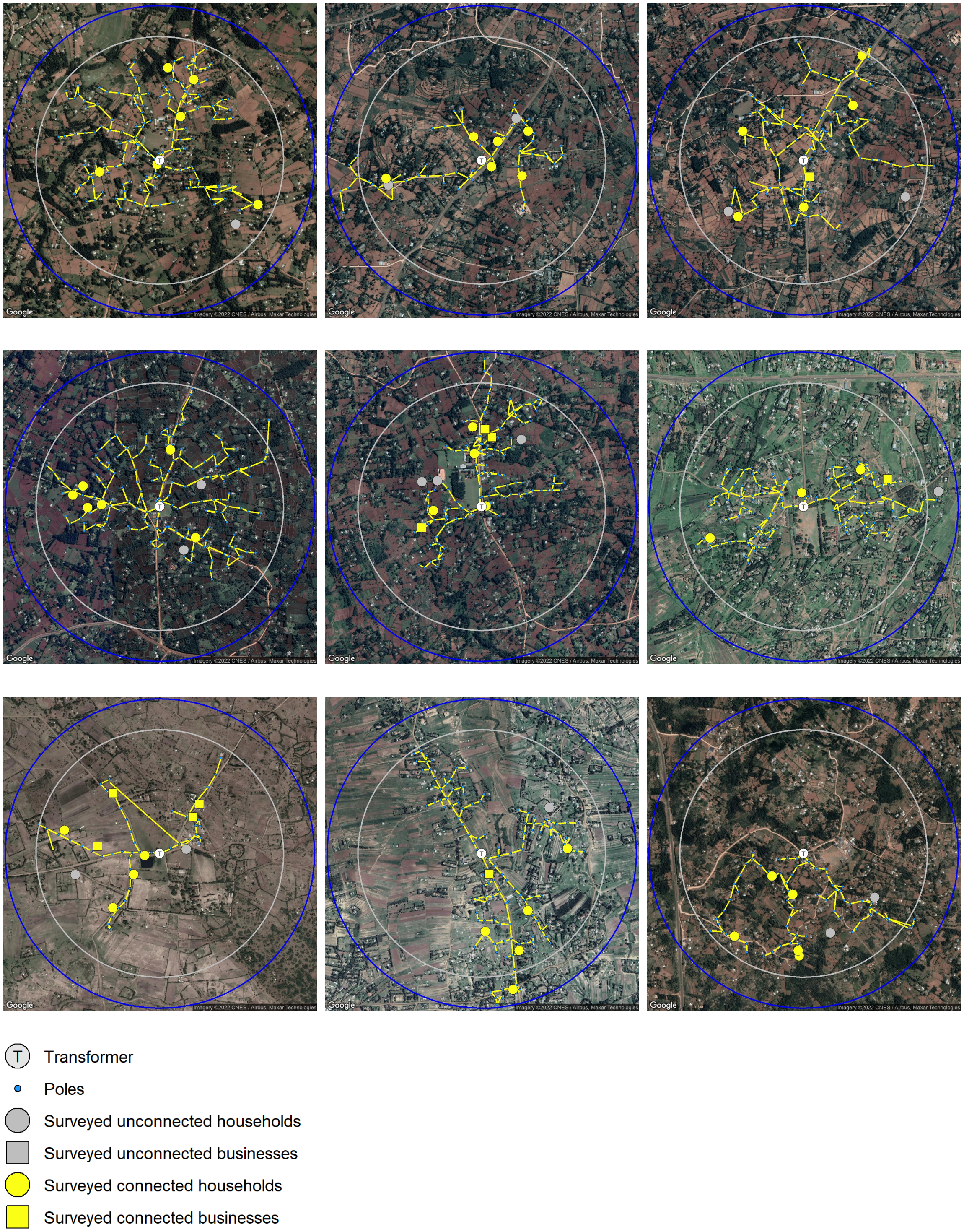
[redacted]
[redacted]
Senior Energy Specialist
The World Bank

[redacted]
[redacted]
Principal Power Engineer
The African Development Bank

[redacted]
[redacted]
Electrification Project Manager
Kenya Power & Lighting Company

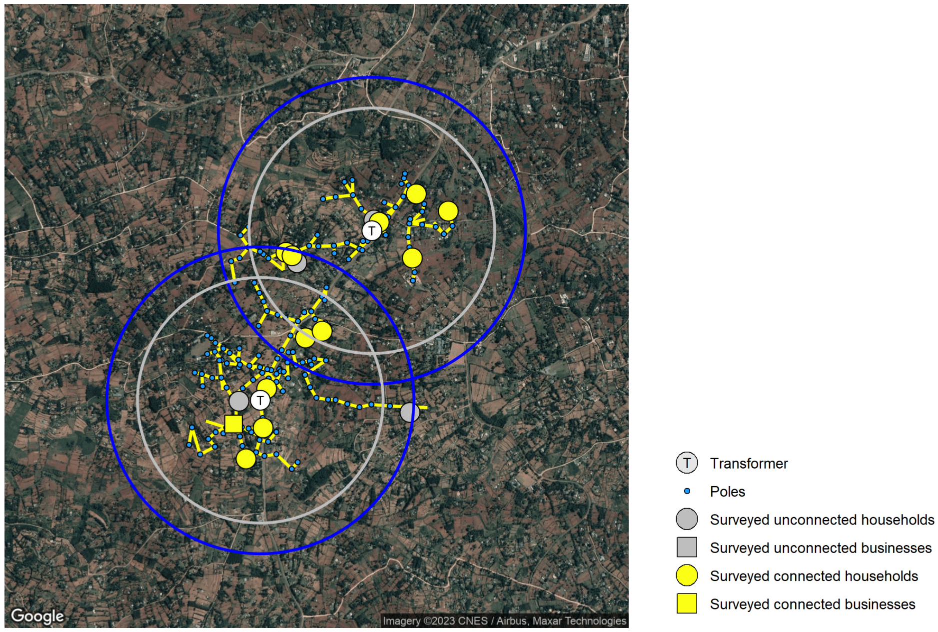
This figure displays the monitoring intervention sent to contractors. All letters were signed by relevant representatives from Kenya Power, the World Bank, and the African Development Bank, with their names and positions listed below. Each letter specified the contractor's name and contact information. The letters were then hand-delivered to management at the relevant contractors by members of our research team to ensure receipt, together with the list of treatment sites referenced in the letter.

Figure A5: Engineering data collected (additional example sites)



These maps display the construction data collected at example sites. The grey line denotes 600 meters and the blue line denotes 700 meters from the transformer ('T') at the center. Subsection 5.1 provides additional information on data collection. To preserve anonymity, random spatial noise has been added to household and business locations.

Figure A6: Two sites located less than 1,200 meters apart

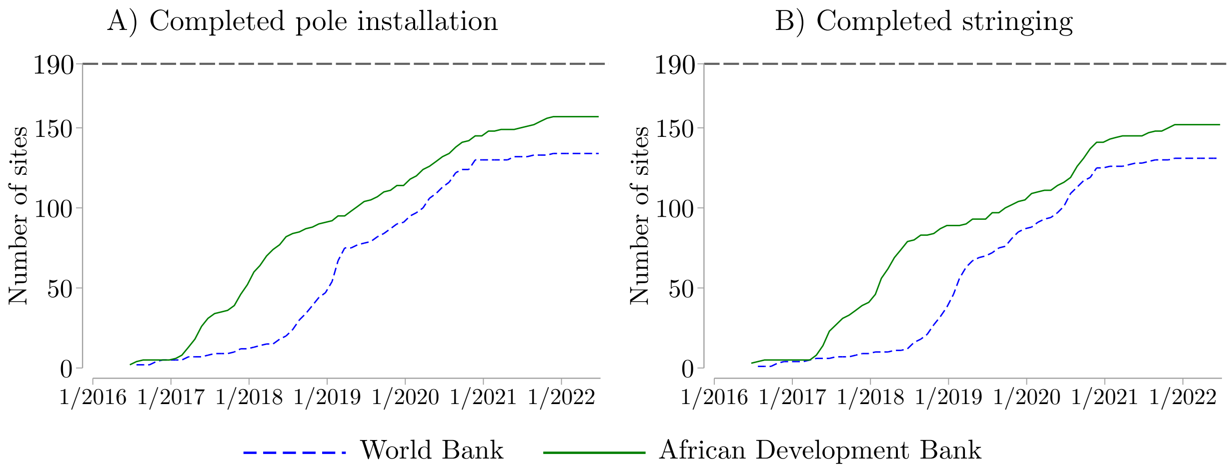


This map displays two sites whose transformers are located 990 meters apart, such that the 600 and 700 meter radius eligibility areas overlap. See Subsection 5.1 for a discussion on this issue. To preserve anonymity, random spatial noise has been added to household and business locations.

Figure A7: A PowerWatch device

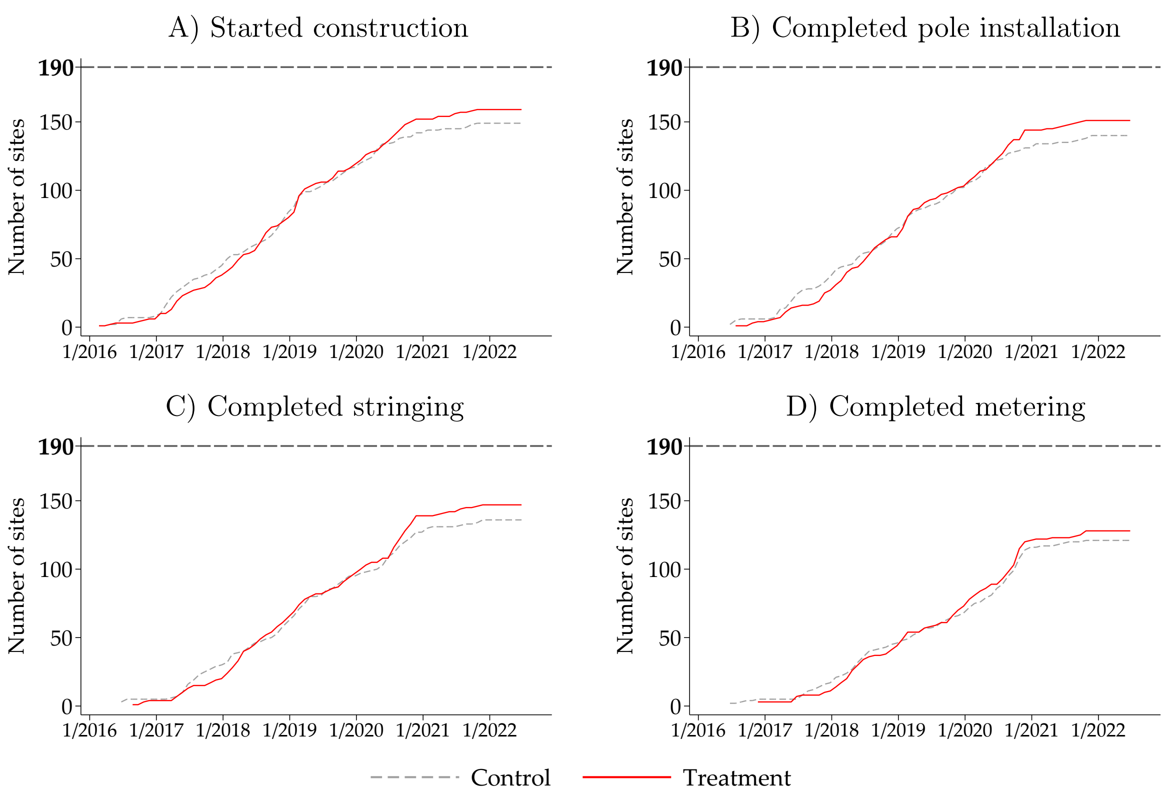
A PowerWatch device, part of nLine's GridWatch technologies used to measure household-level power outages and voltage. The device transmits data to the cloud in near real-time over the cellular network, and stores data locally to transmit later in the case of network failure. The GridWatch server consolidates data to detect patterns in power outages and reduce noisy signals.

Figure A8: Construction progress by funding source



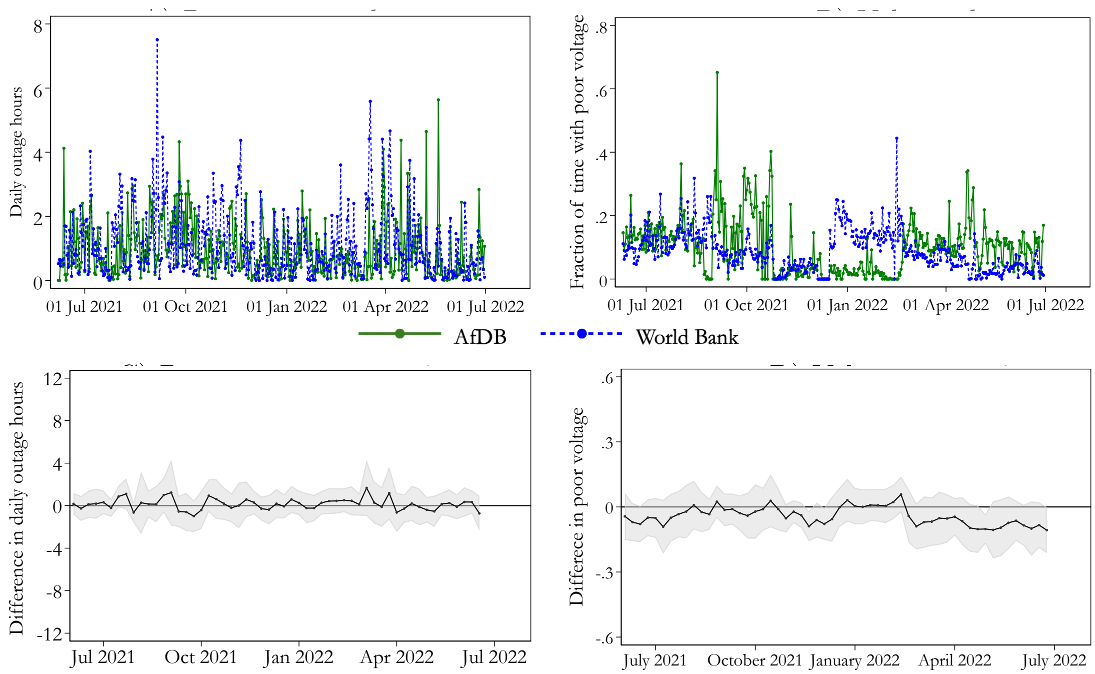
Data for 190 African Development Bank sites and 190 World Bank sites located in the five study counties collected through phone surveys with village representatives. Figure 6 displays progress for pole installation and stringing.

Figure A9: Construction progress by audit treatment status



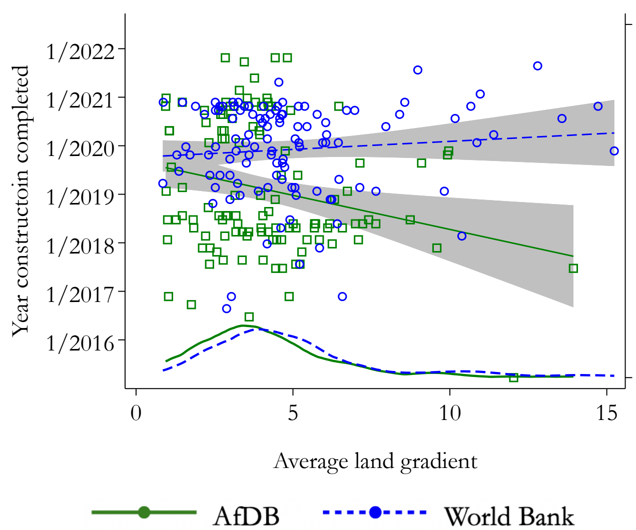
Data for 190 control sites and 190 treatment sites located in the five study counties collected through phone surveys with village representatives.

Figure A10: Reliability and voltage quality by funding source



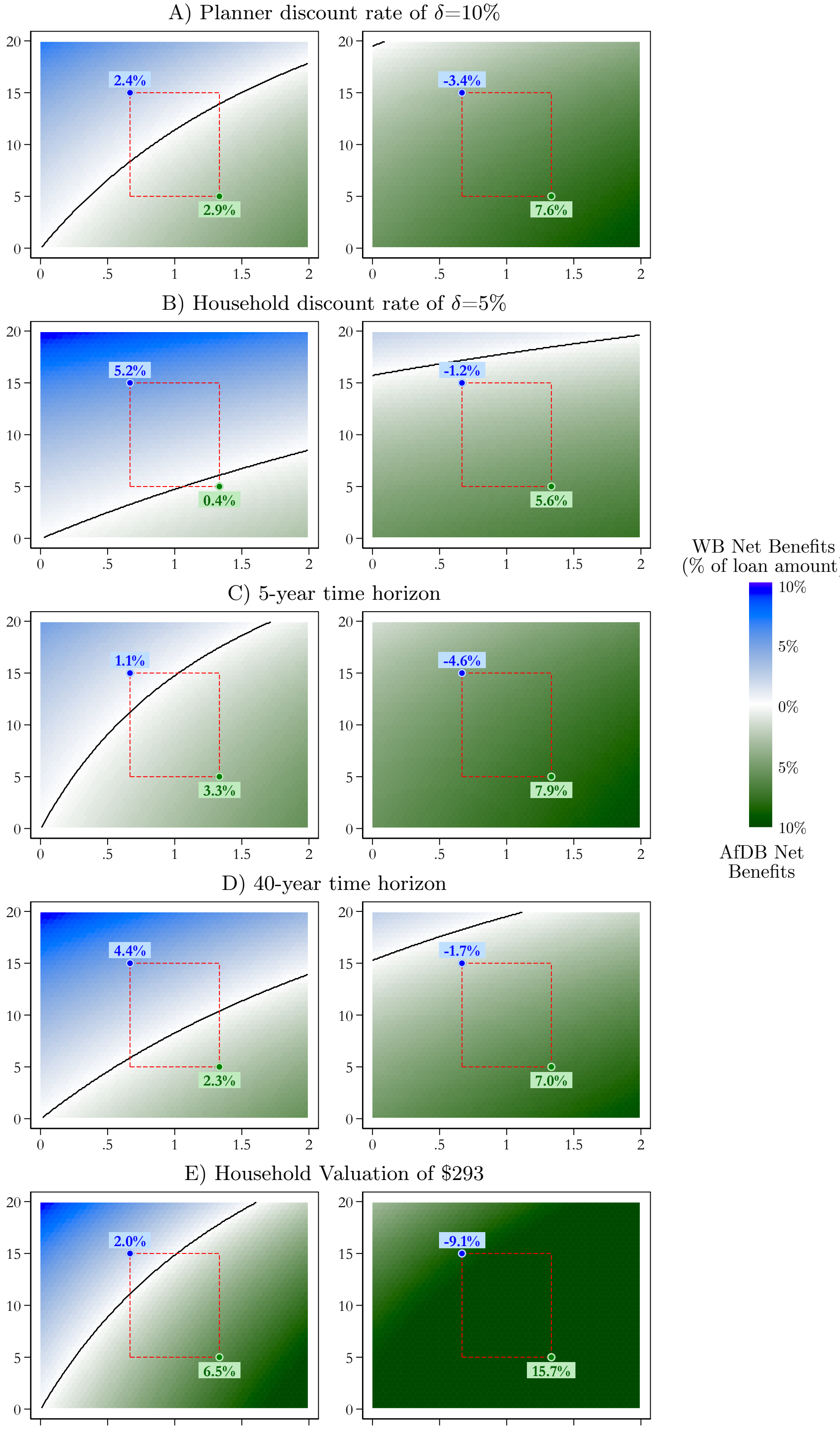
Panels A and B present the hours of power outage per day and fraction of time experiencing poor voltage quality, respectively, for World Bank and African Development Bank sites. Panels C and D estimate a separate coefficient for each week of the sample, with constituency fixed effects and standard errors clustered by site. In the voltage graphs, periods with power outages are set to missing in the voltage measurement data, but the results look similar when coding such periods as having $V = 0$.

Figure A11: Construction delays and land gradient



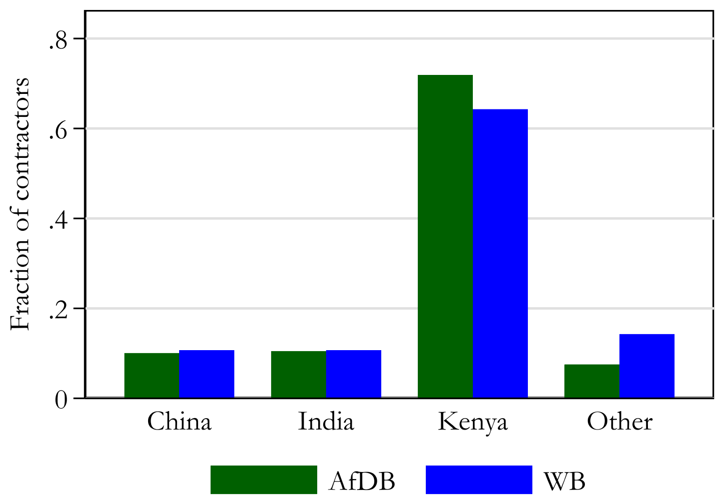
Average land gradient is calculated for each site over the 600 meter radius around its transformer. Land gradient is uncorrelated with construction delays, both unconditionally and conditional on funder. The lag between WB and AfDB is approximately constant across the entire land gradient support. Data source: Shuttle Radar Topography Mission (SRTM) Global Digital Elevation Model. Gradient is measured in degrees from 0 (perfectly flat) to 90 degrees (perfectly vertical) (Dinkelman 2011).

Figure A12: Costs versus benefits on various assumptions



Variations on the assumptions used for Figure 7, which presents results using our preferred assumptions. Each sub-title indicates the one aspect that has been changed relative to Figure 7.

Figure A13: World Bank contractors and African Development Bank subcontractors by country of origin



59 companies were either awarded World Bank (WB) contracts or were approved to subcontract with one of the African Development Bank (AfDB) contractors for the procurement of poles, conductors, cables, or installation. This graph shows the distribution of countries of origin of these 59 companies. AfDB subcontractors are inverse-weighted by the number of good-specific subcontractors for which that AfDB contractor got approval, as most likely only one was used per good.

B Appendix Tables

Table A1: Transformer facility type

Panel A) Sample field data

	N	AfDB Mean (SD)	WB (SE)
Health center	250	0.05	-0.00
		(0.22)	(0.03)
School	250	0.50	-0.13*
		(0.50)	(0.07)
Market center	250	0.17	0.09*
		(0.38)	(0.05)
Religious building	250	0.20	-0.10*
		(0.40)	(0.05)
Other	250	0.08	-0.03
		(0.28)	(0.04)
None	250	0.27	0.12*
		(0.44)	(0.06)

Panel B) Sample administrative data

	N	AfDB Mean (SD)	WB (SE)
Health center	378	0.06	-0.03
		(0.24)	(0.02)
School	378	0.09	0.18***
		(0.29)	(0.04)
Market center	378	0.13	0.03
		(0.33)	(0.04)
Religious building	378	0.05	-0.03
		(0.22)	(0.02)
Other	378	0.09	0.03
		(0.29)	(0.03)
None	378	0.08	0.29***
		(0.27)	(0.04)

Panel C) Nationwide administrative data

	N	AfDB Mean (SD)	WB (SE)
Health center	7396	0.03	-0.02***
		(0.18)	(0.00)
School	7396	0.05	-0.01**
		(0.23)	(0.01)
Market center	7396	0.16	0.01
		(0.37)	(0.01)
Religious building	7396	0.02	0.00
		(0.13)	(0.00)
Other	7396	0.38	0.22***
		(0.49)	(0.01)
None	7396	0.00	0.00
		(0.00)	(.)

Most transformers were constructed between 2005-2015 as part of a push by Kenya's Rural Electrification Authority (REA) to electrify public facilities like schools, religious buildings and markets, and there appear to be some differences in the likelihood of transformers located near specific types of facilities to be assigned to one funder or the other. We test whether transformers connected to certain types of facilities were more or less likely to be assigned to WB or AfDB funding. Total shares can exceed 1 because some transformers are located near multiple public facilities. We test this separately using field data collected during our surveys, administrative data for our entire sample, and nationwide administrative data. All regressions include constituency fixed effects.

Table A2: Summary statistics

	Mean	SD	25^{th}	50^{th}	75^{th}	N
Transformer missing fuse	0.23	0.42	0	0	0	250
Number of transformer lines	3.13	0.99	3	3	4	250
Number of poles	84.92	35.16	58	80	106	250
Number of leaning poles (<85deg)	1.69	2.57	0	1	2	250
Number of cracked poles	20.29	18.01	6	15	29	250
Number of poles without a cap	40.17	28.80	19	34	56	250
Number of stays	54.91	24.34	37	52	70	250
Households surveyed	3.78	1.63	3	4	5	250
Connected households surveyed	3.15	1.64	2	3	4	250
Year households connected	2018.89	1.13	2018	2019	2020	184

Summary statistics for surveyed sites. The question on connection year was added to the survey later, after surveying had already been completed at 66 sites.

Table A3: Impact of transformer characteristics on construction at site

	Uncompleted Mean	Completed	N
World Bank (=1)	0.55	-0.17**	378
	[0.50]	(0.06)	
Baseline nighttime radiance	0.48	-0.21**	366
	[1.03]	(0.07)	
Land gradient	5.55	-1.24***	347
	[3.47]	(0.27)	
Nearest city (KM)	32.46	1.56	347
	[17.21]	(1.59)	
Nearest city (minutes driving)	59.98	1.30	347
	[30.03]	(2.68)	
Public building...			
Health	0.08	-0.03	378
	[0.27]	(0.02)	
Secondary school	0.05	0.03	378
	[0.21]	(0.03)	
Primary school	0.16	0.09	378
	[0.36]	(0.05)	
Market center	0.13	0.01	378
	[0.34]	(0.04)	
Religious building	0.06	-0.03	378
	[0.24]	(0.02)	
None	0.20	-0.00	378
	[0.40]	(0.05)	
School	0.19	0.00	378
	[0.39]	(0.05)	
Other	0.14	-0.06	378
	[0.35]	(0.04)	
Mean	0.66	0.66	

Differences between sites that saw construction and sites that did not, among the tracked sample of 378.

Table A4: Construction timing

	(1) AfDB Mean	(2) World Bank Effect Estimate (β_1)	(3) Audit Treatment Effect, WB Sites (β_2)	(4) Audit Treatment Effect, AfDB Sites (β_3)	(5) N
Outcome 3: Construction timing index	0.00	-0.90***	-0.07	-0.29*	250
	[1.00]	(0.17)	(0.16)	(0.17)	
LMCP construction start date (months since Jan 2015)	37.22	10.18***	1.66	4.00**	250
	[11.38]	(1.90)	(1.72)	(1.93)	
Pole erection completion date (months since Jan 2015)	45.20	9.90***	1.85	3.52	249
	[15.17]	(2.67)	(2.49)	(2.59)	
Stringing completion date (months since Jan 2015)	46.91	9.47***	1.33	2.70	247
	[15.48]	(2.76)	(2.52)	(2.56)	
Metering completion date (months since Jan 2015)	47.73	15.67***	-1.23	4.71*	226
	[14.56]	(2.48)	(2.17)	(2.65)	
months between construction start and pole erection complete	7.83	-0.06	0.18	-0.32	249
	[10.19]	(1.81)	(1.63)	(1.52)	
months between pole erection complete and stringing complete	1.90	-0.73	-0.48	-0.53	246
	[4.41]	(0.80)	(0.64)	(0.68)	
months between stringing complete and metering complete	0.95	6.25***	-2.01*	0.37	224
	[8.04]	(1.53)	(1.20)	(1.47)	

The construction timing index (shown here in row 1) is a standardized average of sub-components shown in the remaining rows. All outcomes are measured at the site level and collected via surveys with village representatives (described in section 5).$^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A5: Primary engineering and socioeconomic outcomes with funder–audit interaction

	WB Effect Estimate	Audit Treatment Estimate	Interaction Estimate	N
Outcome 1: Construction quality index	0.64***	-0.03	0.13	250
	(0.21)	(0.18)	(0.28)	
Outcome 2: Network size and configuration index	-0.04	-0.08	0.27	244
	(0.16)	(0.18)	(0.24)	
Outcome 3: Construction timing index	-0.90***	-0.29*	0.22	250
	(0.17)	(0.17)	(0.24)	
Outcome 4: Household installation quality index	0.05	0.23*	-0.21	944
	(0.12)	(0.12)	(0.17)	
Outcome 5: Household cost, experience, bribery index	0.13	0.11	-0.06	944
	(0.12)	(0.10)	(0.16)	
Outcome 6: Reliability and safety index	-0.11	-0.01	0.04	944
	(0.13)	(0.11)	(0.18)	
Outcome 7: Knowledge index	0.14	0.07	-0.07	944
	(0.10)	(0.10)	(0.14)	
Outcome 8: Electricity Usage index	0.12	0.28**	-0.17	944
	(0.13)	(0.13)	(0.17)	

Outcome variables are indices constructed from groups of variables standardized to have mean 0 and standard deviation 1. Each column presents results when the treatment variable is either: (1) WB funding source, or (2) the randomized audit treatment. In rows 1–3, observations are transformer sites; standard errors are shown in parentheses. In rows 4–8, observations are individual respondents. Table 5 presents a version with separate treatment effects. All regressions control for site land gradient and public facility type. Standard errors are clustered by transformer site and shown in parentheses. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A6: Construction quality

	(1) AfDB Mean	(2) World Bank Effect Estimate (β_1)	(3) Audit Treatment Effect, WB Sites (β_2)	(4) Audit Treatment Effect, AfDB Sites (β_3)	(5) N
Outcome 1: Construction quality index	0.00	0.64***	0.10	-0.03	250
	[1.00]	(0.21)	(0.20)	(0.18)	
∗ Transformer does not have bypassed fuse	0.40	-0.15*	-0.05	-0.08	250
	[0.49]	(0.08)	(0.08)	(0.08)	
Pole does not have a crack ≥1cm	0.74	0.05	0.00	-0.01	21022
	[0.44]	(0.03)	(0.03)	(0.03)	
Pole leaning at ≥85 degrees	0.97	0.01*	0.01*	0.00	21229
	[0.16]	(0.00)	(0.00)	(0.00)	
Line has ≥0.5m horiz clearance	0.93	-0.03***	0.01	-0.02**	19780
	[0.25]	(0.01)	(0.01)	(0.01)	
Pole has cap	0.28	0.33***	0.03	0.06	17900
	[0.45]	(0.04)	(0.04)	(0.04)	
Stay/strut properly installed	0.92	0.01	-0.01	0.00	3193
	[0.27]	(0.02)	(0.01)	(0.02)	
Stay/strut installed when required	0.79	0.16***	0.02	0.01	9811
	[0.41]	(0.03)	(0.02)	(0.04)	
Insulator properly installed	0.99	-0.02*	0.00	-0.00	3076
	[0.10]	(0.01)	(0.01)	(0.01)	
Insulator installed when required	0.98	0.01*	-0.01*	0.01	3103
	[0.13]	(0.01)	(0.01)	(0.01)	
Pole has grounding wire	0.34	0.03**	0.01	-0.02*	21229
	[0.47]	(0.01)	(0.01)	(0.01)	

The construction quality index (shown here in row 1) is a standardized average of sub-components shown in the remaining rows. Transformer bypassed fuse is measured once at each site. All other outcomes are measured for all poles measured in the engineering assessment survey (described in Section 5.1). For each pole-level outcome, the sample is limited to poles for which that outcome can be assessed. Standard errors are clustered by site. An F-test of $H_0 : \beta_1 - \beta_3 = 0$ for the metering completion date has a p-val< 0.001. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A7: Network configuration

	(1) AfDB Mean	(2) World Bank Effect Estimate (β_1)	(3) Audit Treatment Effect, WB Sites (β_2)	(4) Audit Treatment Effect, AfDB Sites (β_3)	(5) N
Outcome 2: Network size and configuration index	0.00	-0.04	0.19	-0.08	244
	[1.00]	(0.16)	(0.16)	(0.18)	
Absolute Deviation in Pole Count (relative to design)	65.66	-3.87	6.44	2.46	197
	[55.90]	(11.44)	(11.26)	(12.42)	
Absolute Deviation in Drop Cables (relative to design)	62.12	15.69	-0.07	11.78	178
	[44.79]	(9.57)	(9.49)	(10.49)	
Fraction of compounds at site, within 100m of LV line, electrified	0.89	-0.02	0.04	-0.01	244
	[0.13]	(0.02)	(0.03)	(0.02)	
Fraction of poles ≤600m from transformer	0.95	0.02	0.01	0.00	244
	[0.08]	(0.01)	(0.01)	(0.01)	
Number of poles in design	134.51	-1.10	-8.89	12.52	197
	[87.55]	(15.32)	(16.60)	(15.92)	

The network size and configuration index (shown here in row 1) is a standardized average of sub-components shown in the remaining rows. All outcomes are measured at the site level. Compound data is collected in the household and firm survey data (described in Section 5.2). Pole data is collected in the engineering assessment survey (described in Section 5.1). $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A8: Household installation quality

	(1) AfDB Mean	(2) World Bank Effect Estimate (β_1)	(3) Audit Treatment Effect, WB Sites (β_2)	(4) Audit Treatment Effect, AfDB Sites (β_3)	(5) N
Outcome 4: Household installation quality index	-0.00	0.05	0.02	0.23*	944
	[1.01]	(0.12)	(0.11)	(0.12)	
Outcome 4 (omitting readyboard question)	-0.01	0.15	-0.03	0.23*	944
	[1.00]	(0.12)	(0.12)	(0.12)	
Electricity has flowed to this household (=1)	0.81	0.05	0.04	0.08	944
	[0.39]	(0.06)	(0.04)	(0.05)	
Household has ≥1 meter (=1)	0.86	0.09**	0.01	0.08*	944
	[0.35]	(0.04)	(0.04)	(0.04)	
Household has meter that has worked (=1)	0.77	0.06	0.07	0.11**	943
	[0.42]	(0.06)	(0.05)	(0.05)	
Household has a readyboard (=1)	0.26	-0.14***	0.08**	0.02	944
	[0.44]	(0.04)	(0.04)	(0.05)	
(-) Number of unrequested meters (of hhs w/ meter)	0.51	-0.04	0.10*	0.09	713
	[0.50]	(0.07)	(0.06)	(0.06)	
(-) Weeks from paperwork to receiving meter (of hhs w/ meter)	13.64	4.32	1.58	-2.09	884
	[25.10]	(2.95)	(2.32)	(2.47)	
(-) Weeks from meter to receiving electricity (of hhs with elec)	2.43	-0.26	0.93*	-0.82*	761
	[4.12]	(0.44)	(0.54)	(0.46)	

The household installation quality index (shown here in rows 1 and 2) is a standardized average of sub-components shown in the remaining rows. Row 2 omits the ready board question as the absence of a ready board is not strictly an indication of poor quality. All outcomes are measured at the household level and collected in the household and firm survey data (described in Section 5.2). For outcomes marked with a (-), a higher value indicates a lower quality. For all other outcomes, a higher value indicates higher quality. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A9: Household cost, experience, and bribery

	(1) AfDB Mean	(2) World Bank Effect Estimate (β_1)	(3) Audit Treatment Effect, WB Sites (β_2)	(4) Audit Treatment Effect, AfDB Sites (β_3)	(5) N
Outcome 5: Household cost, experience, bribery index	0.02	0.13	0.06	0.11	944
	[0.99]	(0.12)	(0.11)	(0.10)	
Days given to fulfill paperwork reqs (of LMCP hh)	42.29	21.09	0.30	3.16	828
	[79.87]	(14.35)	(13.54)	(11.70)	
Did not require own wiring before connection (=1)	0.77	-0.03	-0.04	0.01	855
	[0.42]	(0.05)	(0.05)	(0.05)	
(-) KSH spent on wiring (of hh that did wiring) (w)	7774.45	-925.05	645.25	-741.25	708
	[6779.96]	(718.32)	(666.29)	(739.09)	
(-) Up-front connection payment (Ksh) (w)	6684.48	-694.60	588.85	-685.49	925
	[9104.41]	(844.78)	(776.80)	(923.51)	
Connected by KPLC/REA (=1)	0.98	0.01	0.01	0.01	837
	[0.13]	(0.02)	(0.01)	(0.01)	
Was not asked for bribe (=1)	0.91	0.02	-0.02	-0.01	944
	[0.29]	(0.03)	(0.03)	(0.03)	
Didn't do unpaid manual labor for connection (=1)	0.96	-0.02	0.04**	0.00	929
	[0.19]	(0.02)	(0.02)	(0.02)	
(-) Amount paid so far in installments (Ksh) (w)	2698.65	-24.92	-454.06	-48.46	878
	[4531.45]	(521.88)	(467.42)	(504.09)	
Satisfaction with electricity installation (1-5 scale)	4.21	-0.02	0.04	0.08	944
	[1.07]	(0.13)	(0.12)	(0.13)	
(-) Hours in past month with very low voltage	1.57	2.85	1.07	-1.80	602
	[6.61]	(1.86)	(1.73)	(1.67)	
(-) Repair costs for devices damaged b/c electricity (Ksh)	31.19	-9.37	-44.27**	-67.32**	604
	[206.11]	(32.01)	(22.40)	(33.07)	

The household cost, experience, and bribery index (shown here in row 1) is a standardized average of sub-components shown in the remaining rows. All outcomes are measured at the household or firm level and collected in the household and firm survey data (described in Section 5.2). For outcomes marked with a (-), a higher value indicates a lower quality. For all other outcomes, a higher value indicates higher quality. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A10: Household and firm reliability and safety

	(1) AfDB Mean	(2) World Bank Effect Estimate (β_1)	(3) Audit Treatment Effect, WB Sites (β_2)	(4) Audit Treatment Effect, AfDB Sites (β_3)	(5) N
Outcome 6: Reliability and safety index	0.01	-0.11	0.03	-0.01	944
	[0.99]	(0.13)	(0.14)	(0.11)	
Had power in past 7 days (=1) (of electrified hh)	0.88	0.06	-0.02	0.11^{***}	787
	[0.32]	(0.04)	(0.04)	(0.03)	
No regular blackouts (=1) (of electrified hh)	0.58	-0.11^{**}	0.03	-0.05	787
	[0.49]	(0.06)	(0.06)	(0.06)	
No blackout in past 7 days (=1) (of hh w/ power last 7 days)	0.40	0.01	0.01	0.07	703
	[0.49]	(0.07)	(0.07)	(0.07)	
(-) Hours power not working in past 7 days (of hh w/ power last 7 days)	7.12	1.74	-2.86^{*}	0.56	700
	[15.04]	(1.91)	(1.66)	(1.86)	
No blackouts $\geq$30 days in past year (=1) (of electrified hh)	0.95	-0.06	0.01	-0.02	787
	[0.23]	(0.04)	(0.04)	(0.03)	
No injury fr/ electricity in past year (=1) (of electrified hh)	0.99	0.00	-0.02	-0.01	787
	[0.10]	(0.01)	(0.01)	(0.01)	
No damage fr/ electricity in past year (=1) (of electrified hh)	0.99	-0.01	0.00	-0.02^{**}	787
	[0.09]	(0.01)	(0.01)	(0.01)	

The household reliability and safety index (shown here in row 1) is a standardized average of sub-components shown in the remaining rows. All outcomes are measured at the household or firm level and collected in the household and firm survey data (described in Section 5.2). For outcomes marked with a (-), a higher value indicates a lower quality. For all other outcomes, a higher value indicates higher quality. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A11: Knowledge

	(1) AfDB Mean	(2) World Bank Effect Estimate (β_1)	(3) Audit Treatment Effect, WB Sites (β_2)	(4) Audit Treatment Effect, AfDB Sites (β_3)	(5) N
Outcome 7: Knowledge index	0.01	0.13	-0.02	0.06	944
	[1.01]	(0.09)	(0.09)	(0.10)	
Told correct total cost of connection (=1) (of hh w/ drop cable)	0.29	0.05	0.02	0.02	930
	[0.46]	(0.06)	(0.07)	(0.06)	
Correctly told to pay monthly (=1) (of hh told of connxn cost)	0.05	-0.05^{***}	0.02	0.00	930
	[0.22]	(0.02)	(0.01)	(0.02)	
Knows how much still owed for connection (=1)	0.43	0.16^{***}	-0.07	0.02	944
	[0.50]	(0.06)	(0.06)	(0.06)	
Knows 20th token costs same as 1st (=1) (of hh who have topped up)	0.76	0.02	-0.02	-0.01	707
	[0.43]	(0.06)	(0.07)	(0.06)	
Knows value of 1st token	0.94	0.01	-0.00	0.02	707
	[0.23]	(0.03)	(0.02)	(0.03)	

The knowledge index (shown here in row 1) is a standardized average of sub-components shown in the remaining rows. All outcomes are measured at the household or firm level and collected in the household and firm survey data (described in Section 5.2). $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A12: Electricity Usage

	(1) AfDB Mean	(2) World Bank Effect Estimate (β_1)	(3) Audit Treatment Effect, WB Sites (β_2)	(4) Audit Treatment Effect, AfDB Sites (β_3)	(5) N
Outcome 8: Electricity Usage index	-0.01	0.11	0.11	0.28**	944
	[1.00]	(0.12)	(0.10)	(0.12)	
Electricity is main source of lighting (=1)	0.73	0.06	0.03	0.13**	944
	[0.44]	(0.06)	(0.05)	(0.05)	
Electricity is main source of cooking (=1)	0.00	0.00	0.00	0.00	944
	[0.00]	(.)	(.)	(.)	
Household has topped up (=1) (of hh w/	0.86	0.02	0.08**	0.11**	836
prepaid meter)	[0.35]	(0.05)	(0.03)	(0.05)	
Electricity spending past month (Ksh) (of hh	183.13	-9.93	-0.35	11.54	893
w/ meter) (w)	[241.18]	(24.36)	(19.53)	(25.43)	
Hours of lighting used at night in past week	2.78	0.10	0.29	0.40	848
	[2.74]	(0.29)	(0.20)	(0.30)	
Hours of lighting used in morning in past	4.66	0.63	1.50**	0.32	652
week	[5.69]	(0.77)	(0.74)	(0.70)	
Number of appliances that use the grid	1.90	0.31*	0.08	0.32**	938
	[1.51]	(0.17)	(0.17)	(0.16)	
Number of households in this compound	1.13	0.01	0.01	0.03	944
connected	[0.67]	(0.04)	(0.04)	(0.06)	

The electricity usage index (shown here in row 1) is a standardized average of sub-components shown in the remaining rows. All outcomes are measured at the household or firm level and collected in the household and firm survey data (described in Section 5.2). $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A13: Household Socioeconomic Outcomes

	(1) AfDB Mean	(2) World Bank Effect Estimate (β_1)	(3) Audit Treatment Effect, WB Sites (β_2)	(4) Audit Treatment Effect, AfDB Sites (β_3)	(5) N
Outcome 9: Household socioeconomic outcomes index	-0.02	0.24*	-0.01	0.20	944
	[0.99]	(0.12)	(0.13)	(0.12)	
Connection allowed pursuing employment, business (1-5) (of connected hh)	2.54	0.27*	0.33**	0.16	787
	[1.19]	(0.15)	(0.14)	(0.15)	
Connection affected earnings (1-5) (of connected hh)	3.25	0.15*	0.09	0.01	787
	[0.78]	(0.09)	(0.09)	(0.09)	
Connection permitted changing hours worked (1-5) (of connected hh)	3.65	0.05	0.05	0.04	787
	[0.86]	(0.12)	(0.12)	(0.11)	
Connection affected amount of food consumed (1-5) (of connected hh)	3.10	0.14**	0.03	0.08	787
	[0.45]	(0.05)	(0.05)	(0.06)	
Connection affected health (1-5) (of connected hh)	3.59	-0.08	0.08	-0.05	787
	[0.86]	(0.11)	(0.10)	(0.11)	
Connection affected children's education (1-5) (of connected hh w/ children)	4.32	0.33***	-0.04	0.19*	691
	[0.85]	(0.09)	(0.08)	(0.10)	
Connection affected knowledge about news (1-5) (of connected hh)	4.15	0.14	0.01	0.10	787
	[0.97]	(0.10)	(0.09)	(0.10)	
Connection permited changing kerosene spending (1-5) (of connected hh)	1.51	-0.03	0.06	0.07	787
	[0.99]	(0.10)	(0.10)	(0.10)	
Connection changed phone charging freq. (1-5) (of connected hh)	3.11	0.57***	-0.13	0.36**	787
	[1.49]	(0.18)	(0.19)	(0.17)	
(-) Kerosene spending, last week (Ksh) (w)	30.02	-15.21**	15.52**	-8.91	940
	[62.30]	(6.04)	(6.32)	(5.80)	
Owns home (=1)	0.99	0.00	-0.01	0.00	944
	[0.10]	(0.01)	(0.01)	(0.01)	
Number of rooms in primary residence	3.54	-0.19	-0.05	0.08	944
	[1.66]	(0.15)	(0.13)	(0.14)	
High-quality floors (=1)	0.38	0.04	-0.12***	-0.02	944
	[0.48]	(0.05)	(0.05)	(0.05)	
High-quality roof (=1)	1.00	-0.01*	0.00	0.01	944
	[0.06]	(0.01)	(0.01)	(0.01)	
High-quality walls (=1)	0.21	0.01	-0.00	0.06	944
	[0.41]	(0.04)	(0.04)	(0.04)	
Buildings in compound (of compounds with hh)	2.94	-0.15	-0.01	-0.18	747
	[1.56]	(0.15)	(0.13)	(0.20)	
Electrified buildings in compound (of compounds with hh)	1.64	-0.04	0.01	0.14	747
	[1.31]	(0.10)	(0.08)	(0.16)	

The household socioeconomic outcomes index (shown here in row 1) is a standardized average of sub-components shown in the remaining rows. All outcomes are measured at the household or firm level and collected in the household and firm survey data (described in Section 5.2). For outcomes marked with a (-), a higher value indicates a lower quality. For all other outcomes, a higher value indicates higher quality. Due to ambiguity in the wording for one of the survey questions, a pre-specified outcome ("connection affected security") was removed from this table. The wording of the survey question allowed the respondent to interpret the question two different ways. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A14: Firm Performance

	(1) AfDB Mean	(2) World Bank Effect Estimate (β_1)	(3) Audit Treatment Effect, WB Sites (β_2)	(4) Audit Treatment Effect, AfDB Sites (β_3)	(5) N
Outcome 10: Firm Performance Index	-0.00	0.29	-0.11	0.12	373
	[1.00]	(0.19)	(0.21)	(0.17)	
Firm uses electricity (=1)	0.64	0.20**	0.02	0.11	339
	[0.48]	(0.08)	(0.08)	(0.08)	
Firm planning to buy electrical equipment in next year (=1)	0.42	0.13	-0.11	0.06	339
	[0.49]	(0.10)	(0.09)	(0.08)	
Firm uses elec beyond lighting and cell charge (=1) (of those that use elec)	0.36	-0.08	0.00	-0.19**	344
	[0.48]	(0.09)	(0.08)	(0.07)	
Number of appliances owned by Firm	1.23	0.24	-0.13	0.03	344
	[1.13]	(0.24)	(0.24)	(0.20)	
Firm household has high quality roof (=1)	0.89	0.07	-0.08	0.03	306
	[0.31]	(0.06)	(0.06)	(0.06)	
Firm household has high quality walls (=1)	0.49	-0.04	0.04	0.11	306
	[0.50]	(0.12)	(0.10)	(0.10)	

The firm performance index (shown here in row 1) is a standardized average of sub-components shown in the remaining rows. All outcomes are measured at the firm level and collected in the household and firm survey data (described in Section 5.2). $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A15: Household Political and Social Beliefs

	(1) AfDB Mean	(2) World Bank Effect Estimate (β_1)	(3) Audit Treatment Effect, WB Sites (β_2)	(4) Audit Treatment Effect, AfDB Sites (β_3)	(5) N
Outcome 11: Political and Social Beliefs index	0.00	0.03	0.01	0.03	944
	[0.99]	(0.08)	(0.08)	(0.09)	
HH electrification in top 2 most-important govt policies (=1)	0.21	0.00	-0.01	-0.01	944
	[0.41]	(0.04)	(0.04)	(0.04)	
Thinks govt doing good job providing electricity (=1)	0.98	0.00	-0.00	-0.01	944
	[0.14]	(0.01)	(0.01)	(0.01)	
Voted in August 2017 election (=1)	1.15	0.07	0.35	0.48	944
	[4.42]	(0.20)	(0.33)	(0.35)	

The household political and social beliefs index (shown here in row 1) is a standardized average of sub-components shown in the remaining rows. All outcomes are measured at the household or firm level and collected in the household and firm survey data (described in Section 5.2). $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A16: Impact of gradient and facility type on construction delays

Panel A) Months to stringing completion

	(1)	(2)	(3)	(4)	(5)
World Bank (=1)	6.8***	9.9***	9.5***	9.5***	8.7***
	(2.1)	(2.2)	(2.3)	(2.3)	(2.5)
Land gradient			0.6		0.4
			(0.6)		(0.7)
Health center				-0.3	1.1
				(5.4)	(5.7)
Secondary school				-0.4	-1.3
				(3.3)	(3.4)
Primary school				1.8	2.6
				(2.4)	(2.6)
Market center				1.1	1.9
				(2.7)	(2.9)
Religious building				-3.9	-4.0
				(2.9)	(3.0)
Other				2.7	4.9
				(5.8)	(6.3)
Observations	246	246	229	226	211
Constituency FE	No	Yes	Yes	Yes	Yes

Panel B) Months to metering completion

	(1)	(2)	(3)	(4)	(5)
World Bank (=1)	9.6***	12.4***	11.7***	13.2***	12.2***
	(1.8)	(1.8)	(1.9)	(1.9)	(2.0)
Land gradient			1.0*		0.8
			(0.5)		(0.6)
Health center				3.7	5.3
				(4.5)	(4.6)
Secondary school				0.9	0.4
				(2.7)	(2.7)
Primary school				1.3	1.6
				(2.0)	(2.1)
Market center				-2.0	-1.1
				(2.2)	(2.3)
Religious building				1.4	1.3
				(2.4)	(2.5)
Other				3.8	6.5
				(4.7)	(5.1)
Observations	248	248	231	227	212
Constituency FE	No	Yes	Yes	Yes	Yes

Stringing (metering) was completed at WB sites on average 6.8 (9.6) months later than at AfDB sites when pooling audit control and treatment sites. Controlling for land gradient and facility type does not affect these estimates meaningfully, and land gradient and facility type appear largely uncorrelated with time to stringing and metering completion. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A17: Heterogeneity in WB delay by facility type

	Time to stringing completion (months)				
	(1)	(2)	(3)	(4)	(5)
World Bank (=1)	18.5	5.2	8.8*	-6.0	-3.0
	(13.5)	(6.9)	(5.0)	(5.3)	(14.6)
Observations	9	64	53	17	21
Control Mean	41.5	53.16	50.52	43.1	54.36
Sample	Health centers	Schools	Market centers	Religious buildings	Others

While there are small differences between funder type in the facility type associated with each transformer (Table A1) this does not drive heterogeneity in the impact of WB conditionality on construction delays when compared with AfDB sites. $^* \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A18: Primary engineering and socioeconomic outcomes excluding Lots 3 and 5

	(1) WB Effect Estimate (β_1)	(2) Audit Treatment Effect, WB Sites (β_2)	(3) Audit Treatment Effect, AfDB Sites (β_3)	(4) N
Outcome 1: Construction quality index	0.57	0.13	0.05	161
	(0.50)	(0.49)	(0.19)	
Outcome 2: Network size and configuration index	0.66	-0.16	-0.07	156
	(0.40)	(0.37)	(0.20)	
Outcome 3: Construction timing index	-1.13***	-0.15	-0.36**	161
	(0.38)	(0.39)	(0.17)	
Outcome 4: Household installation quality index	-0.55**	0.79***	0.23*	592
	(0.26)	(0.23)	(0.13)	
Outcome 5: Household cost, experience, bribery index	0.39**	0.11	0.11	592
	(0.19)	(0.18)	(0.10)	
Outcome 6: Reliability and safety index	-0.12	-0.18	-0.08	592
	(0.16)	(0.17)	(0.10)	
Outcome 7: Knowledge index	0.31	-0.09	0.10	592
	(0.20)	(0.20)	(0.10)	
Outcome 8: Electricity Usage index	-0.24	0.53***	0.25*	592
	(0.31)	(0.19)	(0.14)	
Outcome 10: Firm Performance Index	-0.27	0.08	0.02	256
	(0.42)	(0.43)	(0.17)	
Outcome 11: Political and Social Beliefs index	0.01	-0.02	0.02	592
	(0.16)	(0.13)	(0.09)	

This table replicates Table 5 but excludes Lots 3 and 5 and then retains only a balanced panel of constituencies. Subsection 6.6 provides more detail. $^* \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A19: Connections and poles installed per site excluding nearby sites

	Entire site				Outside 600 meter boundary			
	Poles		Connections		Poles		Connections	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
β_1: World Bank (=1)	-12.8**	-5.5	-13.4**	-22.2*	-2.4***	-1.7	-1.6***	-1.4
	(6.2)	(10.7)	(6.7)	(11.5)	(0.7)	(1.2)	(0.6)	(1.0)
Treatment (=1)	9.0		6.7		0.2		0.1	
	(6.2)		(6.6)		(0.7)		(0.6)	
β_2: Treatment (WB sites)		-2.4		8.6		-0.6		-0.4
		(9.2)		(9.9)		(1.0)		(0.8)
β_3: Treatment (AfDB sites)		18.7**		4.3		0.9		0.7
		(8.8)		(9.5)		(1.0)		(0.8)
Observations	224	224	224	224	218	218	218	218
Control Mean	93.33	93.33	73.30	73.30	3.77	3.77	2.98	2.98

This table replicates Table 3 but excluding sites that are less than 1,200 of another site, as the areas within 600 meters of such sites would overlap (see Subsection 5.1 for a discussion of this problem). If anything, this version more strongly supports our results. All regressions include constituency fixed effects. Standard errors shown in parentheses. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A20: Heterogeneity by share of contractor's sites under audit

Outcome 4: Household installation quality index	
Treated	0.31***
	(0.11)
Treated x	-0.25**
ManyTreated	(0.13)
Outcome 5: Household cost, experience, bribery index	
Treated	-0.02
	(0.11)
Treated x	0.14
ManyTreated	(0.13)
Outcome 6: Reliability and safety index	
Treated	-0.12
	(0.13)
Treated x	0.13
ManyTreated	(0.16)
Outcome 7: Knowledge index	
Treated	-0.02
	(0.11)
Treated x	0.07
ManyTreated	(0.13)
Outcome 8: Electricity Usage index	
Treated	0.32***
	(0.11)
Treated x	-0.19
ManyTreated	(0.12)
Test for null hypothesis of equal treatment effects for all outcomes: p=0.252	

This table tests whether audit treatment effects differ across contractors that had a higher percentage of their sites in the treatment group. Outcome variables are indices constructed from groups of variables standardized to have mean 0 and standard deviation 1. "Treated" is a binary variable that equals 1 if the occupant is at a treated site. "ManyTreated" is a binary variable if the occupant's site is assigned to the contractor with the highest percentage of sites in the audit treatment group for its funder. All equations include constituency fixed effects, funder fixed effects, census controls, and land gradient and public facility type controls (given some baseline imbalance along these dimensions) and were jointly estimated using seemingly unrelated regression. Standard errors are clustered by site and shown in parentheses. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

C Conceptual framework

Consider a principal who has a project that they want to contract out to one or more firms, selected from a continuum of firms ($\gamma_i \in [0, \infty)$) through competitive auction. Firm i is differentiated by its firm type γ_i which incurs convex cost $c(\gamma_i)$. Firms can exert effort e_i at convex cost $d(e_i)$ with $d'(0) = 0$ and $d(0) = 0$. Each firm's output quality is the sum of its type and effort: $q_i = \gamma_i + e_i$.

The project consists of three components: design, materials, and installation. Each firm can provide at most one component. Overall project quality is the sum of the three components: $Q = q_a + q_b + q_c$. The principal can award these as one bundled contract ($t = 1$) or as three unbundled contracts ($t = 3$). The principal also imposes a minimum firm type threshold $\bar{\gamma}$ that determines firms' eligibility to submit a bid.

The principal can furthermore implement either low monitoring ($m = L$) or high monitoring ($m = H$). Setting $m = H$ allows the principal to enforce a minimum output quality threshold $\bar{q}$ for each component. If any component is produced below output quality $\bar{q}$, then the contracted firm is not paid.

The auction proceeds as follows:

(P1) The principal chooses and announces the two auction parameters (t and m).

- If the contracts are unbundled, the principal runs three sequential competitive auctions.
- If the contract is bundled, the principal runs one competitive auction for installation. The installer later selects a designer and a supplier with full discretion.

(A1) Each eligible firm decides whether to bid. If it chooses to bid, it chooses a bid amount b_i.

(P2) The principal identifies the lowest eligible bid as the winner of each auction.

- If the contracts are unbundled, the principal awards three contracts.
- If the contract is bundled, the principal awards one contract for installation. The winner then selects a designer $\gamma_a \in [0, \infty)$ and a supplier $\gamma_b \in [0, \infty)$ with full discretion. The installer can mandate their effort levels e_a and e_b.

(A2) Each firm exerts effort e_i and realizes their output quality q_i.

(P3) The principal pays the contractor(s) (or not).

- If $m = L$, all firms are paid regardless of q_i.
- If $m = H$ and $t = 1$, all firms are paid only if $q \geq \bar{q}$ for each component (and the installer pays the designer and supplier *iff* it is paid).
- If $m = H$ and $t = 3$, the designer, supplier, and installer are each paid only if their respective output quality is at least $\bar{q}$.

Finally, assuming perfect competition:

- If $t = 1$, the firm's bid is $b_c = c(\gamma_a) + d(e_a) + c(\gamma_b) + d(e_b) + c(\gamma_c) + d(e_c)$. The firm pays the design firm $c(\gamma_a) + d(e_a)$ and the supplies firm $c(\gamma_b) + d(e_b)$.
- If $t = 3$, each firm's bid is $b_i = c(\gamma_i) + d(e_i)$.

Case 1 ($t = 3, m = L$):

- Firms with $\gamma_i = \bar{\gamma}$ will bid $c(\bar{\gamma})$ and win all three auctions.
- There is no incentive to supply any effort, so $e_i = 0$
- Project quality will be $3\bar{\gamma}$, with cost per contract $b(3, L) = c(\bar{\gamma})$ and total cost $3c(\bar{\gamma})$

Case 2 ($t = 3, m = H$):

- For each component, the winning firm is the one that can produce output quality $\bar{q}$ at lowest cost, since no other firm can bid lower than them while achieving at least zero profit. The winning firms will each have type γ_i and choose e_i such that: $c'(\gamma_i) = d'(e_i)$. Let γ^* and e^* be the solution to this problem.
- Project quality will be $\bar{q}$, with cost per contract $b(3, H) = c(\gamma^*) + d(e^*)$ and total cost of $3c(\gamma^*) + 3d(e^*)$.

Case 3 ($t = 1, m = L$):

- The winning firm has $\gamma = \bar{\gamma}$ and bids $c(\bar{\gamma}) + 2c(0)$ in the auction. It is the firm of at least type $\bar{\gamma}$ that can bid the lowest. It then exerts no effort.
- For design and materials, it has no incentive to select firms with more than minimum firm type, and it will contract assuming zero effort from those firms.
- Project quality will be $\bar{\gamma}$, with total cost $b(1, L) = c(\bar{\gamma}) + 2c(0)$.

Case 4 ($t = 1, m = H$):

- With full ability to contract on firm type and effort exerted, the winning firm will wish to supply output quality $\bar{q}$ at minimum cost. The winning firm that is able to bid the lowest will have γ_c^* and choose effort level e_c^*; and will seek to contract design and materials firms with type and levels of effort $\gamma_a^*, e_a^*, \gamma_b^*, e_b^*$ such that: $c'(\gamma_a) = d'(e_a) = c'(\gamma_b) = d'(e_b) = c'(\gamma_c) = d'(e_c)$.
- Project quality will be $\bar{q}$, with total cost $b(1, H) = 3c(\gamma^*) + 3d(e^*)$..

D Additional background information and analyses

In 2014, Kenya's Ministry of Energy and Petroleum (MoE) published the Draft National Energy Policy, establishing a list of policies and strategies to *"increase rural electrification connectivity to at least 40% by 2016 and 100% by 2020"* and to *"seek funding from development partners for specific programmes especially...in rural electrification projects."* (MoE 2014). In Kenya Power's 2014-2015 annual report, they note that *"The KShs 4 Billion receivable from the GoK is part of a larger commitment by the GoK, to be financed partly through support from the World Bank and the African Development Bank to enhance universal access to electricity."* In May 2015, Kenya's President Uhuru Kenyatta announced the launch of the LMCP, with a goal of connecting *"one million new customers to electricity each year"* (Kenya Presidency 2015). In a press conference two weeks after President Kenyatta's announcement, Kenya Power's then- Managing Director Ben Chumo added that the program was designed to facilitate *"the government's objective of providing 70% households with electricity by 2017 and universal access by 2020"* (Kenya Power 2015b).[26] While not quite reaching these ambitious targets, the program has been effective: nationwide household electricity access was reported to have increased from 25% in 2009 to 70% in 2019 (KNBS 2009, 2019). Many of the rural transformers selected for the LMCP had been constructed between 2005 and 2013 as part of a nationwide push by Kenya's then- Rural Electrification Authority (REA)[27] to connect all public facilities—such as markets, schools, health centers, and water points—to electricity (REA 2008, Berkouwer et al. 2018).

In November 2017 the AfDB signed 15 additional turn-key contracts to begin maximization of an additional 5,200 sites as part of its *Phase II* (which we do not examine in this study).

D.1 Upfront connection costs

Beneficiaries under the LMCP are connected via 'pre-paid' meters, meaning they must buy electricity credits in advance of using electricity. Once they consume all of their prepaid electricity, they lose access to electricity, and only regain access only after they buy more credits. Households usually prevent this by purchasing additional credits before their credits run out.

To recover the \$150 connection fee, Kenya Power initially enrolled households into a payment plan consisting of 36 monthly installments of around \$4 per month. The charge was automatically added to households' accounts on a monthly basis, and any electricity payments the household made were directed towards paying off this debt prior to being directed towards electricity credits. However, this generated a significant barrier for households: as an example, if a household runs out of electricity credit in January, and then does not consume any electricity in February or March, they would have to pay at least \$16.01—4 months worth of connection fees—to be able to consume any electricity in April. The contribution was thus later capped at 50% of any topup amount (Kassem et al. 2022).

This barrier was not only a significant financial hurdle, but one that was unanticipated and poorly understood. According to Kenya Power, households should have been informed of the payment structure as part of the consent process, which was the very first step in the construction process, but it is unclear whether this consent process was regularly implemented in practice. To verify whether this process was correctly implemented, and to test whether donor conditionality and monitoring can improve adherence to these guidelines, the household survey (described in Subsection 5.2) measures respondent understanding of the aggregate costs of an electricity connection under the LMCP. 58%

[26] This target date was later extended to 2022, which was also not met.

[27] Since renamed Rural Electrification and Renewable Energy Corporation (REREC).

of households do not recall ever having been told that they would have to pay Kenya Power for the connection.

An additional financial hurdle was the upfront cost of wiring, which the LMCP later tried to address by providing ready boards. In a May 2015 address, President Kenyatta described this policy as follows: *"The Ministry of Energy has also come up with designs that will enable households that do not have internal wiring in their houses to use electricity by providing a 'ready board'... [it] has switches, sockets and bulb holders and those who do not have wiring in their houses will be able to use electricity as soon as they are connected*" (Kenya Presidency 2015).

D.2 Informal and illegal connections

Illegal connections are much more common in urban areas than they are in rural areas like the villages where the LMCP was implemented. Many households in urban contexts, especially those living in informal settlement areas, are sufficiently close to the existing grid that they can be connected via a simple drop cable, which can usually be done by a local handyman at relatively low cost. Given the low population density in rural areas, connection of an additional household usually requires constructing at least one additional electricity pole, which requires more sophisticated engineering techniques. In our survey, only 2.7% of households with a working electricity connection did not have a meter. Of these, 93% said they had not been metered yet but would be metered soon, and 20% said they had not yet done the internal wiring that was required prior to connection. Nobody stated the reason they did not have a meter was because theirs was an illegal connection. Of course, these survey responses come with the usual caveats about survey questions relating to illegal behavior

D.3 Unconnected households

The LMCP's objective was to connect all unconnected households to electricity, however, in practice connectivity was not universal. At the average site at least 7% of compounds were not connected to the grid, and at the 90th percentile site at least 25% of households were not connected.[28] The most common reason (given by 31% of unconnected respondents) is that they were not present or available during the days on which construction or sign-up were administered. Second, even though the LMCP program specifications indicate there were to be no upfront connection fees, 23% of respondents still report having been unable to pay, often because they were not able to afford the internal wiring required by Kenya Power to be connected: 16% of unconnected households report this to be the reason. This suggests that despite efforts to provide free ready boards to low-income households, the cost of household wiring remained a barrier that prevented some households from getting connected.

Households could choose not to get connected, but in practice this was rare. Statistics are not available nationwide, but Lee et al. (2020) found that at most 4% of participants in a rural sample in western Kenya randomly selected to receive a free electricity connection chose not to receive one.

Some households preferred to get more than one meter in their compound, for example to leverage the lifeline tariff, or for independence between the households residing in the compound.

[28] Enumerators only counted unconnected compounds that were within connection distance of the existing electricity network, so this may be an underestimate. Subsection 5.1 provides more details on surveying methodology.

D.4 Experiences with bribery

Households also report numerous instances of bribery. In our household survey data, 8% of households connected under LMCP had been explicitly asked for money by the contractor, with amounts generally ranging from \$5 to \$50. Tragically, a small number of households report having paid an individual claiming to be a contractor, only to never hear from them again and to remain unconnected. 5% of unconnected households report not wanting a connection, for example because they are simply not interested in having electricity or because they think electricity is unsafe (this is similar to the rate reported in Lee et al. (2020) noted above).

D.5 Contractors

Contractors that bid on LMCP contracts are generally medium-to-large construction firms with a track record of completed projects. Contractors that won the AfDB- and WB-funded LMCP contracts were a mix of Kenyan firms and international firms, with some joint ventures comprised of two or more firms. To qualify, bidders must satisfy certain requirements related to financial capacity, prior experience including with similarly sized jobs, and any record of sanctioning and litigation.

The winners of the 12 AfDB contracts had been selected from 110 bidders. Six of the 10 turnkey contracts winners were Kenyan while four were foreign (Capital Business 2015). The set of contractors awarded WB contracts also included a mix of Kenyan and International firms, with Kenyan firms primarily awarded bids for the supply of wooden and concrete poles.

There is no blanket provision preventing firms from submitting—or being awarded—bids with both donors simultaneously. Indeed, many of the AfDB contractors named above have in the past bid on—and in many cases been awarded—WB contracts. International procurement can be thought of as a repeated game: poor contract performance can have serious ramifications on long-term outcomes. Several LMCP contractors have been debarred at least once by the WB or the AfDB (Kenya Power 2018b; Spotlight East Africa 2020). For example, in October 2018 the WB Sanctions Board imposed "a sanction of debarment" on the Indian company Angelique International for "fraudulent practices as defined in Paragraph 1.16(a)(ii) of the January 2011 Procurement Guidelines." (WB 2017; WB 2011).

Many of the pole supply firms had existing relations with Kenya Power even prior to the start of the LMCP. As an example, public minutes from a pre-bid meeting for wooden pole procurement organized by Kenya Power in 2014 indicate that eight of the wooden pole suppliers that won WB contracts or AfDB sub-contracts for the LMCP in 2016-2017 were already engaging with Kenya Power as early as 2014, well before the launch of the LMCP (Kenya Power 2016b), and in many cases even before that (Business Daily 2007).

D.6 Oversight

The materials inspections for both funders required detailed mechanical and chemical inspections of 10 poles out of each batch of 500 poles. These visits would usually take place at the physical factory (often located in India, China, or Kenya). However, a number of factory assessments between 2020-2022 had to be conducted via Zoom for public health reasons.

The funders' oversight structures were similar: the WB's project manager managed 22 cluster and site supervisors across six offices nationwide, while the AfDB's project manager managed 19 cluster and site supervisors across four offices nationwide. The consultants' primary activities during the construction process included conducting site-level spot checks, collecting monthly progress reports from contractors, and hosting (at least) monthly meetings with Kenya Power and each respective contractor.

D.7 Robustness tests

We begin by assessing potential endogeneity concerns related to the assignment mechanism raised in Subsection 4.1. First, WB-funded sites have a 13% higher average land gradient. It is plausible that hilliness slows construction and that this difference explains the WB delays. We therefore examine whether land gradient hay have caused any of the difference in construction delays by funder assignment. Land gradient is uncorrelated with construction delays, both unconditionally and conditional on funder: the WB delays persist in a stable manner when controlling for land gradient (Table A16). Furthermore, lag between WB and AfDB is approximately constant across the entire land gradient support (Figure A11). The difference in land gradient is therefore unlikely to explain the results. Second, WB sites are significantly less likely to be located near a secondary school or religious building, and more likely to be located near a market center or no public facility at all (Table A1). The gap in timing between WB and AfDB sites is not significantly different across facility types (Table A17), and the gap in timing between WB and AfDB sites persists when controlling for facility type (Table A16). All results in Table 5 control for facility type, which do not qualitatively affect the results. Evaluated together, these analyses make it unlikely that baseline differences in facility type contribute meaningfully to the results.

The GridWatch devices recorded data between June 2021 and June 2022, even though stringing at most AfDB sites was completed between 2017 and 2019 and stringing at most WB sites was completed between 2018 and 2020. Thus, the GridWatch data measured WB sites when they were on average one year newer than the AfDB sites surveyed at the same time. If the aging of the grid negatively affects reliability and voltage quality, then this bias would favor WB in the results. Figure A14 confirms that voltage quality is constant over time, and that the lack of difference in voltage quality between the WB and the AfDB persists even among sites where the time since stringing completion was approximately equal.

For Outcome 4 measuring household installation quality (Table A8) we replicate the index omitting the question asking the respondent whether they have a ready board, since it is not obvious whether the presence of a ready board is a positive or negative component. Its presence simultaneously indicates Kenya Power provisions and a lack of household preparedness (see Subsection 3.6 for more detail).

Of the 250 sites that we surveyed, 26 are located less than 1,200 meters from another site. Given that AfDB sites saw construction on average earlier than WB sites, this could reduce construction at WB sites, as the subset of that site's unconnected households that lie within the 600 meter radius of the nearby site might already have been connected. This could explain why Table 3 indicates less construction at WB sites. To test this, we replicate this table excluding the 26 sites—12 AfDB and 14 WB—that are within 1,200 of another site. Table A19 shows the results. If anything, the gap between construction at WB and AfDB sites is even larger.

Finally, the private contractor awarded lots 3 and 5 of the WB construction contracts[29] experienced unusual financial circumstances and this may have interfered with the timeliness and quality of their construction. We therefore repeat the analysis from Table 5 excluding these contracts, and then only keeping a balanced panel of counties. This does not affect results: if anything, household installation quality and reliability and safety were slightly worse at the remaining WB sites, although the results are noisier (Table A18).

[29] A single consortium won both of these contracts.

D.8 Cost-benefit calculations

The cost-benefit calculations in Section 7 make several simplifying assumptions. They value quality differences according to discounted future costs to replace poles at the end of their useful life. The calculations assume that other maintenance costs are similar, despite differences in construction quality. Each pole is assumed to have a constant probability of failure in any given year. The total number of new connections nationwide is assumed to be as reported in citepKenyaPower20171108. Meanwhile, consistent with survey data from the five counties study area, the total number of poles is assumed to be 1.51 times the total number of new connections. We assume a uniform replacement cost of $100 per pole (for materials alone), consistent with contract amounts and discussion in (Muthike and Ali 2021). While the procurement cost per pole was different for AfDB and WB contracts during the LMCP, Kenya Power, not the multilateral donor, is responsible for long-term maintenance and repair and would thus procure these items independently. We assume that about half of total replacement costs is for materials alone, which is roughly consistent with contract amounts in the WB Phase I construction.

D.9 Resilience

Construction might affect resilience through two key engineering channels. First, voltage quality tends to worsen with distance from the central transformer.[30] We find that this is primarily due to the increasing number of customers connected more closely to the transformer rather than the distance traveled along the LV electricity wire per se. Table A21 shows no difference between funders in distance resilience.

Table A21: Resilience of voltage to distance from transformer

	(1)	(2)	(3)
Distance Along Wire	-0.000	-0.000	-0.000
	(0.003)	(0.003)	(0.003)
Customer Connections	-0.490***	-0.490***	-0.615***
	(0.160)	(0.163)	(0.230)
World Bank		0.043	-0.788
		(1.305)	(2.741)
World Bank=1 × Distance Along Wire			-0.002
			(0.008)
World Bank=1 × Customer Connections			0.261
			(0.347)
Constant	237.937***	237.918***	238.452***
	(1.345)	(1.459)	(1.507)
Observations	377314	377314	377314
Control Mean	235.69	235.69	235.69

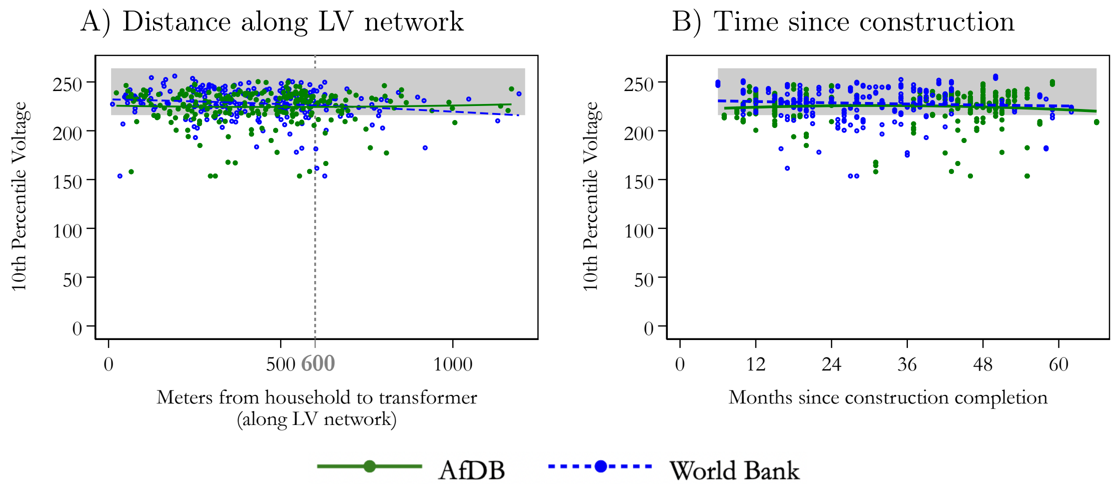
Standard errors are clustered by respondent and shown in parentheses. $^{*} \leq 0.10$,$^{**} \leq .05$,$^{***} \leq .01$.

Panel A of Figure A14 explores the correlation between 10th percentage of voltage quality and distance to the transformer along the LV network.[31] There does not appear to be a significant

[30] Jacome et al. (2019) find a similar result in Zanzibar, Tanzania.

[31] The results look similar when using mean voltage. Using the 10th percentage of voltage quality is in line with engineering expectations around how resilience might affect voltage quality.

Figure A14: Voltage quality resilience to distance and infrastructure aging



10th percentile of hourly voltage readings with quadratic fit line. The gray area indicates Kenya's nominal voltage, 240 V, ±10% as per international utility guidelines. Panel A explores how a household's distance to the central transformer (as measured along the LV network) affects voltage quality. Panel B explores how the passage of time since the initial completion of construction affects voltage quality. Neither appear to strongly affect voltage quality. WB and AfDB exhibit similar trends.

or discontinuous decline after 600 meters, the eligibility cutoff for a subsidized LMCP household connection, suggesting greater returns to scale might have been achieved under a higher distance eligibility cutoff.

Second, voltage quality could worsen with the passage of time, as infrastructure ages. Higher quality construction might make infrastructure more resilient and slow any associated decay. The time since construction varies across our sample since stringing was completed between June 2017 and January 2021, while GridWatch devices recorded data between June 2021 and June 2022. Panel B of Figure A14 examines the correlation between voltage quality and time since construction. At both AfDB and WB sites, the grid appears resilient to aging for the first five years after the completion of stringing.

E List of individuals engaged in qualitative interviews

Qualitative research included detailed in-person (or on Zoom, where required due to Covid-19) conversations with key leadership personnel at Kenya Power, World Bank, African Development Bank, and the Consultant charged with supervising construction. An asterisk (*) indicates that a single position was held by different individuals at different points in time.

- World Bank employees:
  - Practice manager, Global energy and extractives practice, Africa region
  - Senior energy specialist, Kenya country team
  - Energy finance specialist, Kenya country team
- African Development Bank employees:
  - Principal power engineer*
  - Principal power engineer*
- Kenya Power employees:

  - General manager of connectivity
  - General manager of infrastructure development
  - LMCP Contract Project Manager (AfDB Phase I)
  - LMCP Project Leader (AfDB Phase I)
  - LMCP Contract Project Manager (WB)
  - LMCP Project Leader (WB)
  - LMCP Project Leader for (AfDB Phase II)
- Project Management Consultant employees:
  - Senior Manager