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**Working Paper**

# Reforming the Electric Power Industry in Developing Economies

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## Evidence on Efficiency and Electricity Access Outcomes

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*Abstract* – Since the 1990s, many developing countries have restructured their electric power industry. Policies such as breaking up, commercializing and privatizing utilities, allowing for independent power producers, installing independent regulators, and introducing competitive wholesale markets were meant to improve the industry's efficiency and service quality. We exploit more than 30 years of data from over 100 countries to investigate the impact of power sector reforms on efficiency (represented by network losses) and access to electricity (represented by connection rates and residential power consumption). Crucially, reforms are likely to be endogenous with respect to sector performance: a crisis in electricity supply might well trigger reform efforts. We deal with endogeneity using reform activity in neighboring countries as an instrument. Our results suggest that reforms strongly and positively impact electricity access. According to our preferred specification, a full reform program would increase connection rates by 20 percentage points and per capita consumption by 62 percent: these are large effects that are stable across a range of robustness checks. Moreover, the effect of improving access is largest in South Asian countries. In contrast to previous studies, we do not find robust evidence to support the theory that reforms reduce network losses.

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# Contents

# 1. Introduction

Reforms in the West. After World War II, the electric power industry was considered a natural monopoly; across the world, utilities were usually regulated and often state-owned. In the late 1980s, the first countries introduced reforms intended to liberalize segments of the industry, in particular, power generation. Among these countries were Norway, the United Kingdom, parts of the United States, and Chile. Today, large parts of Europe and the U.S. feature free entry of new power generators, separation of generation from transmission, independent regulatory oversight of monopolistic grids, free trade between producers and (large) consumers, and competitive price formation on wholesale markets. While restructuring the electricity industry did not live up to all expectations, most observers conclude that the benefits have outweighed the costs (Newbery, 2004; Borenstein and Bushnell, 2015).

Reforms in the developing world. In the 1990s, reform activities spilled over to the developing world, where they were encouraged by the World Bank's lending policies as well as the competition norms of international trade partners (Bacon and Besant-Jones, 2002; Wamukonya, 2003; Woodhouse, 2006). The fully-fledged textbook reform program, which was propagated at that time, entailed several steps: breaking up state-owned and -run power utilities and requiring them to operate under commercial and corporate principles, privatizing state-owned enterprises, liberalizing power generation and allowing for independent power producers, installing independent regulatory agencies, and introducing competitive wholesale and possibly retail markets (Joskow, 2008; Bacon, 2018). In many developing economies, however, problems in the electricity sector were—and still are—different from those in industrialized countries. Among the most pressing issues are poor security of supply due to a lack of generation capacity, high levels of electricity theft, low electrification rates and a tradition of electricity consumption subsidies (Besant-Jones, 2006). It was hoped that reforms would improve efficiency and technical performance, attract private finance, and unburden government budgets (Bacon and Besant-Jones, 2002; Bacon, 2018). Given these different preconditions in developing economies, the question arises whether the market-based reform model pioneered in the industrialized world is helpful for tackling the challenges of less-developed power sectors.

Losses and access. Two particularly pressing problems in developing countries that are largely absent in most industrialized countries are high non-technical transmission and distribution (T&D) losses—power theft—and limited electricity access, reflected by low connection rates and low levels of residential power consumption. Both outcomes represent core challenges for electricity provision in developing economies; thus, they are closely intertwined. Electricity access is considered a key ingredient of economic and social development. A lack of affordable and comprehensive electricity supply hampers human well-being and income-generating opportunities, leaving households and businesses unable to afford connection charges and increasing power theft. This, in return, jeopardizes the cost recovery of utilities and thus prevents them from making urgently needed investments targeted at scaling up generation capacity and improving or expanding technical infrastructure. As a result, power sectors are locked into a highly inefficient state. In Sub-Saharan Africa and South Asia, T&D losses remain, on average, between two to three times as high as they are in countries that belong to the Organisation for Economic Co-operation and Development (OECD), while in some places, less than half of the population has access to power (WDI 2018; World Bank, 2019). Against this backdrop, empirically investigating the impact of power sector reforms on these two outcomes, T&D losses and electricity access, is highly relevant.

This study. This study assesses the impact of power sector reforms in developing economies using regression analysis based on panel data on up to 108 countries between the years 1985 and 2016.[1] Reform activity is measured as a composite index, which reflects the *de jure* implementation of up to eight different reform steps as documented by Urpelainen and Yang (2018). We estimate the impact of these reforms on two distinct potential outcomes by testing the following hypotheses: (i) reforms reduce power losses and (ii) reforms improve electricity access, both in terms of power connection rates and residential electricity consumption. We chose these sectoral performance indicators over macro-level indicators, such as GDP or the Gini-index, as the former are more immediately affected by reform activities in the sector. By looking at both connection rates and per capita electricity consumption, we assess a multidimensional concept of access that goes beyond mere physical connection. This enables us to detect whether increased connectivity is offset by poor reliability and unaffordable supply. Furthermore, we allow for reforms to take on region-specific effects to paint a more differentiated picture of how the impact of reforms varies across different contexts.

Endogeneity. Perhaps the most fundamental issue to the empirical identification of the impacts of reform activity is the endogeneity of reforms: reforms may not only affect sector performance, but they might (also) be induced by sector performance. For example, reforms might be triggered by either poor performance (i.e., high losses or low access). Alternatively, only countries with high-performing electric power industries—due to broader good governance and policy, for example—might take up reforms in the first place. In both cases, a simple panel estimation of the effect of reforms on performance would yield biased estimates and cannot be interpreted as a causal relationship. (In fact, we find evidence that supports the "problems trigger reforms" hypothesis.) To address endogeneity, we employ an instrumental variables (IV) identification strategy first utilized by Urpelainen *et al.* (2018), which uses reforms in neighboring countries as an instrument for domestic reform activity. Similar identification strategies were previously used to address policy endogeneity in other areas, such as by Giuliano *et al.* (2013) and Acemoglu *et al.* (2019) who instrument for democracy, and by Sen and Vollebergh (2016) instrumenting for carbon taxes on energy use.

Contributions. Since 2004, more than two dozen papers have used econometric models to evaluate the impact of power sector reforms, including a few recent IV-based studies. Our contribution to the empirical IV literature on power sector reforms is threefold. First, we study

[1] Our sample comprises low-income developing economies and emerging economies, both of which will be subsumed under the umbrella term "developing economies" from here on.

electricity access, which we measure with two distinct indicators, connection rate and residential per capita consumption. Second, we assess region-specific effects. Finally, we extend data coverage by at least three years and provide a range of robustness tests.

Findings. Our findings suggest that reforming the electricity industry is beneficial for electricity access. The impact of these reforms is significant and robust across our two performance indicators as well as a wide series of model specifications and robustness tests. Our preferred specification suggests that a fully-fledged set of reforms increases connection rates by as much as 20 percentage points and per capita consumption by 62 percent; these are very large effects. Regional variation in the effectiveness of reforms is significant, with the benefits of reforms being particularly pronounced in South Asia. These findings are vastly understated in an Ordinary Least Squares (OLS) regression, a fact that supports the "crisis triggers reform" hypothesis about the endogeneity of reform. By contrast, we cannot find robust evidence of any impact of reforms on T&D losses. While our preferred specification is marginally statistically significant, the size and direction of the coefficient, as well as its statistical significance, are quite sensitive to our assumptions. We conclude that market-oriented reforms in the electric power industry tend to benefit electricity access, but they do not solve all of the sector's problems, in particular, T&D losses.

Structure. The remainder of this paper is organized as follows. We devote Section 2 to reviewing the existing literature on the impacts of reforms. In Section 3, we introduce the data and econometric methodology that we used. We present our empirical results in Section 4 and discuss their robustness in Section 5. Finally, Section 6 concludes.

# 2. Literature review

Studies on reform activities. Researchers have studied power sector reforms in a variety of ways. A substantive share of these analyses were conducted at the World Bank. We believe the following contributions to the research on reform activities in developing economies to be the most interesting. Victor and Heller (2007) study the political economy of reform in five emerging economies, particularly the question of why reform programs have differed from the "textbook" model of reform. Consistent with this finding, Gratwick and Eberhard (2008) observe that after 15 years of reform efforts in the developing world, a new, hybrid power market model has evolved. Vagliasindi and Besant-Jones (2013) analyze how initial conditions, such as income level and power industry size, determine whether embarking on reforms is worthwhile, with a particular focus on unbundling. Lee and Usman (2018) scrutinize political economy drivers and motives for reform uptake and conclude that more inclusively designed reform processes are needed in light of the limited evidence of the benefits of reform. Foster *et al.* (2017) inspect the sequencing, combination, and spatio-temporal diffusion of reforms across a wide range of developing countries. Urpelainen and Yang (2019) similarly evaluate patterns of variation in reform uptake along economic growth indicators and regime type using a new global reform database. Finally, Jamasb *et al.* (2005) focus on the desired reform outcomes and gather core indicators for evaluating performance impact in the sector.

**Studies on the impacts of reform: Overview.** Between 2004 and 2019, more than two dozen papers that use econometric approaches to evaluate the impact of power sector reforms were published. They study a broad range of outcomes, ranging from technical performance (T&D losses, installed capacity, power generation, capacity utilization, and output per worker) and the industry's economic and social performance (access rates, electricity consumption per capita, and consumer prices) to wider macroeconomic metrics (GDP per capita, GDP growth, electricity trade, GINI inequality index, and the Human Development Index). Bensch (2019) and Bacon (2018) provide comprehensive reviews of this literature. Bensch (2019) recognizes that the lack of evidence on electricity access is a crucial gap in the literature, a gap that the present paper addresses. To avoid repeating these recent papers, we focus the following literature review on papers that are similar to ours, in the sense that they contain multi-country panel analyses, study the same outcomes (efficiency and access), and use a comprehensive reform measure as an explanatory variable (as opposed to one single aspect of reform, i.e., a single reform step).

**Studies on the impacts of reform: OLS.** Nagayama (2010), using panel data from 86 countries, finds a loss-reducing effect of regulatory agencies when combined with independent power producers (IPP) and privatization. By contrast, Erdogdu (2011), using similar data and an aggregate reform index, finds that reforms increase losses. Nepal and Jamasb (2012), studying transition countries only, conclude that power sector reforms by themselves have no significant loss-reducing effect unless when complemented with overall market reform. Across these studies, the evidence of the effect of power sector reforms on T&D losses seems inconclusive. Vagliasindi (2012) studies residential power connection rates in 22 countries and finds a positive effect for privatization and regulation but a negative one for partial unbundling on connection rates.

**Studies on the impacts of reform: IV.** While these earlier studies mainly rely on fixed effects to accommodate for unobservable confounders between countries and years, they do not address potential simultaneity between reforms and performance. Three more recent studies deal with the endogeneity of reform by using an IV approach, estimated either via two-stage least squares (2SLS) or generalized methods of moments (GMM). We will discuss these in detail below.

Sen *et al.* (2018) evaluate data from 17 Asian developing countries that was gathered during the years 1990–2013, using both GMM and 2SLS estimations. They study the impact of IPPs, independent regulation, unbundling, corporatization, open or third-party market entry, and distribution privatization on per capita T&D losses, as well as indicators for broader economic and welfare impacts. Individual steps in the reform process seem to affect losses in different ways. The authors find a robust and negative impact for corporatization, while open entry and regulation seem to increase losses. However, as their IV approach treats open entry as the only endogenous reform variable, it is possible that their estimates of the impact of other reform measures still suffer from endogeneity, especially given reform multicollinearity and interactions between different reforms. Also, their sample size is rather small.

Urpelainen *et al.* (2018) analyze a panel of up to 182 countries, covering the years 1982–2011. To identify whether reforms (as an aggregate index) have reduced losses or increased generation capacity, they use one of two instruments—the average number of reforms implemented in a country's region or, alternatively, in its neighboring countries. Across both OECD and non-OECD countries, they find robust evidence showing that reforms significantly reduce losses and increase capacity, while this effect is particularly strong in non-OECD countries. Despite the geographically extensive data at hand, however, the authors only disaggregate estimates according to OECD affiliation, leaving aside regional differences. Furthermore, given the large disparities between OECD- and non-OECD countries in the controls that were used, a pooled estimation across developing and industrialized countries may distort estimates. We thus deem studying a distinct sample to be a more appropriate approach. More critically, the reform dataset the authors used only covers 92 countries, and zero reforms had been assumed for the remaining countries, which are mostly African, Middle-Eastern and Island states. This is an assumption that, as the authors later reported themselves, turned out to be incorrect (Urpelainen and Yang, 2019).

Imam *et al.* (2019) study the privatization, unbundling, and independent regulation in 47 Sub-Saharan African countries that occurred between 2002 and 2013. The authors devise a dynamic system GMM estimator to overcome endogeneity when estimating how reforms affect losses, electricity consumption per capita, and GDP in the presence of institutional corruption. Their results suggest that independent regulation by itself leads to higher consumption but tends to aggravate losses. When combined with privatization, on the other hand, these effects are reversed. Regulation is especially beneficial for consumption and efficiency when corruption is low. While the authors' study is intended to evaluate the interplay between reforms and corruption, it cannot accommodate any reforms prior to 2002 (due to the limited availability of annual corruption data), nor does it consider other reforms that were equally implemented in the region, such as corporatization, liberalization, and IPPs.

**Contributions.** The present study builds on this previous research and extends the literature in three ways. First, we add electricity access as an outcome variable to the IV literature. Access is not only crucial for human and economic development, but also heavily impacted by reforms, as our results suggest. We engage a multidimensional concept of access, i.e., looking at both power connection rates and per capita residential electricity consumption. Second, while previous studies analyzed outcomes either on a regional or global scale, we provide a regionally disaggregated analysis, using reform-region interaction effects. Our findings suggest that the impacts of reform are indeed quite different across regions. Finally, we extend prior studies by at least three years of additional data and use a new dataset with reform data for 142 countries. We also provide a new set of visualizations.

# 3. Empirical strategy

This section describes the data at hand and outlines the identification strategy pursued, including the econometric model, the instrumental variables approach, and the reform-region interaction effect.

## 3.1 Data

**Dataset.** Our empirical analysis is based on an unbalanced panel of annual country-level observations from 1982 to 2016 that includes up to 108 countries. It contains three performance indicators, the explanatory reform variables, and a set of control variables. We present the regional averages of each performance indicator and the reform score in Table 1. We provide an overview of the countries covered in each region in Table A9 of the appendix, while we show descriptive statistics of all variables in Table A8.

**Performance indicators: Losses.** Data on *T&D losses* comes from the World Bank's World Development Indicators (WDI) and cover the period between 1960 and 2014. Power losses are defined as the total electricity generated from primary sources or imported, minus self-consumption by power plants, final consumption, and power exports. Figures are expressed as a share of the total power generation and capture both technical and non-technical power losses between the source of supply and the consumer. Losses range from around six percent in most mature electric power industries to ten to 25 percent in low-income countries. In a few exceptional cases, such as Benin, Haiti, Libya, or Togo, up to 60 percent of power is lost. We prefer T&D losses over other measures of efficiency, such as outages, capacity utilization, and reserve marginals. The number of power outages is of limited use for panel data analysis given the sparse availability of data. Capacity utilization and reserve margins (the gap between total capacity and peak demand) are widely available but more difficult to interpret: additional investment in generation capacity, a positive outcome, will drive down capacity utilization. High reserve margins can result from over-investment in generation capacity or poor electricity access. A shift to renewable energy and structural changes in the temporal pattern of energy demand may also bias these indicators, given the variable nature of wind and solar power (Hirth *et al.* 2015).

**Performance indicators: Connections.** *Power connection rates* from 1990 to 2016 were obtained from the Sustainable Energy for All (SE4ALL) Database constructed by the World Bank and the International Energy Agency (IEA).[2] This rate is measured as the share of the total population that had access to a source of electricity, as reported in representative national household and industry surveys as well as drawn from international sources. While most OECD members have enjoyed near universal electricity access for decades, in many developing

[2] We interpolated one observation for Kosovo in 2010, where the data reported zero electricity access.

countries, the access deficit covers well over half of the population. The spread in electricity coverage in those countries is ample, ranging from below 20 to above 90 percent.

Performance indicator: Consumption. *Electricity consumption* by households between 1990 and 2016 is obtained from the United Nations Statistics Division. We divide national data on households' cumulative annual electricity consumption by a country's population (data from the WDI) to derive the average per capita residential electricity consumption in kWh. As of 2016, consumption levels were well above 1,000 kWh per capita in industrialized countries, and even three to five times higher in oil-rich countries, but were only at two-digit or low three-digit levels in developing nations. As our final sample countries still vary substantially in power sector size, income levels, and connectivity, this indicator is skewed to the right, and hence we apply a log transformation. This also allows us to interpret effects in percentage-changes.

Reform data. The explanatory variables of primary interest to this analysis are power sector reforms. We use data on individual reform steps by year of implementation, between 1982 and 2013, for 142 developing and emerging economies from a recently released dataset by Urpelainen and Yang (2018). The researchers temporally and geographically extend an earlier database by Erdogdu (2011) to construct the most comprehensive dataset to date on power sector reforms in non-OECD countries. For each country and year, this database contains binary indicators for eight power sector reforms steps: corporatization of state-owned utilities, introduction of an independent regulatory agency, liberalization law, legalization of IPPs, vertical and horizontal unbundling, privatization of power providers, wholesale market competition, and choice of suppliers (retail competition). Each reform variable assumes the value of one if there has been a *de jure* enactment of the respective reform step in a given year (or years prior), and a value of zero otherwise. Hence, reform data primarily reflects changes in the legal and institutional framework surrounding the electric power industry, rather than the success or thoroughness of reform implementation.[3] By 2013, the countries that we covered had, on average, implemented four out of eight reforms. Most countries adopted between three and seven reforms. Less than ten percent of the countries adopted none.

Composite reform score. To represent the state of reform in a given country, we follow Urpelainen *et al.* (2018) and Erdogdu (2011) by aggregating the values of all eight individual reform variables for each year to an overall reform score that ranges from zero to eight. In contrast to other studies that have looked at individual reform steps, our reform variable gives an indication of the overall progression of reform throughout the industry. Using an aggregate reform score inevitably blurs differences in the packaging, sequencing, and comprehensiveness of reforms and implies a linear reform impact. While it would be more instructive to identify the differential effects for individual reform steps and their combination, it is nearly impossible to come up with a good instrument for each step. Alternatively, one could group

[3] For more information on the definition of the eight reform variables, see the codebook in Urpelainen and Yang (2018); for descriptive statistics on reform implementation, refer to supplementary information in Urpelainen and Yang (2019).

individual reform steps into clusters. We refrain from doing so, because we see no clear dividing line between steps; thus, a grouping can take many different forms, depending on the underlying theoretical deliberations.

Table 1. Regional developments

| | T&D Losses (%) | | Connection rates (%) | | Electricity consumption p.c. | | Reform score | |
|---|---|---|---|---|---|---|---|---|
| | 1982 | 2014 | 1990 | 2016 | 1990 | 2016 | 1982 | 2013 |
| East Asia & Pacific | 10 | 12 | 60 | 84 | 253 | 599 | 0 | 3.8 |
| East. Europe & Central Asia* | 13 | 7 | 100 | 100 | 673 | 983 | 0 | 5.4 |
| Latin America & Caribbean | 17 | 15 | 78 | 94 | 306 | 707 | 0.2 | 4.5 |
| Middle East & North Africa | 18 | 13 | 86 | 96 | 1280 | 2113 | 0.3 | 3.7 |
| South Asia | 18 | 22 | 30 | 91 | 40 | 210 | 0 | 3.9 |
| Sub-Saharan Africa | 20 | 13 | 17 | 42 | 75 | 154 | 0 | 3.3 |

*Data for years prior to 1991 contain average values from the former Soviet Union.

**Control variables.** In addition, we control for variables reflecting countries' economic, demographic, and political characteristics. Data on real-term GDP per capita, total population, and population density were taken from the WDI; regime-type data was taken from the Center for Systemic Peace Polity. We include data that reflects the relative size and regional integration of a country's power sector from the Energy Information Administration. The measures we use are installed electricity generation capacity in watts per capita and electricity imports and exports in terawatt hours divided by total domestic power generation.

**Descriptive trend analysis.** To gain an impression of how the three performance indicators correlate with reform activity, we plot each of them against time relative to a bunching in reform activity. For this, we first identify five-year windows during which a country has implemented at least five reform steps.[4] We use a window, rather than a point, both to allow for some lag before the reforms take effect and hopefully to lessen the impact of crisis as a trigger for reforms. For each country, we then normalize each indicator by subtracting the respective country mean and plotting it against time relative to the center of the reform window.

## 3.2 Identification

**The model.** Our strategy for identifying the effect of power sector reforms on performance is informed by the presumption that the implementation of structural and regulatory reforms may not be independent of the power sector's performance. It seems plausible to assert that governments often choose to restructure their power sectors in response to unsatisfactory performance. This simultaneity between reform implementation and performance gives rise

[4] In our sample, a total of 39 countries have such a reform window, while 59 countries have at some point implemented at least four reforms within a five-year time frame.

to substantial endogeneity concerns. We therefore employ an instrumental variables strategy for identification and specify the following set of linear equations:

Second stage

$$Y_{it} = \beta_0 + \beta_1 \widehat{Reforms}_{it-3} + \beta_2 X_{it-3} + \alpha_i + \gamma_t + \varepsilon_{it}$$

First stage

$$\widehat{Reforms}_{it-3} = \theta_0 + \theta_1 NeighReforms_{it-3} + \theta_2 X_{it-3} + \delta_i + \mu_t + \pi_{it}$$

Above, $Y_{it}$ represents the performance indicator, that is, either T&D losses, power connection rates, or residential electricity consumption per capita, with $i$ and $t$ denoting country and year subscripts, respectively. $Reforms_{it-3}$ is the total number of reforms implemented in a country, which we instrument for with the average number of reforms across neighbors, $NeighReforms_{it-3}$, in the second stage equation. This instrument is discussed in detail in Section 3.2.1 below. $X$ is a vector of controls. Furthermore, we use country-fixed effects $\alpha_i$ and $\delta_i$ as well as year-fixed effects, $\gamma_t$ and $\mu_t$. $\beta_1$ represents the main parameter of interest, while $\beta_0$ and $\theta_0$ are constant terms. $\varepsilon_{it}$ and $\pi_{it}$ are the residual error terms. Across all specifications, we estimate heteroscedasticity robust standard errors. Moreover, considering that the effects of reform-induced investment or changes in utility management will likely not materialize immediately after reform uptake, both reforms and control variables are lagged by three years.[5]

**Control variables.** We estimate one model with a parsimonious set of controls, that is, a country's per capita GDP, total population, population density, and polity score, and another model with a more comprehensive set. The latter specification additionally controls for characteristics of the power sector, such as the per capita installed generation capacity as well as the share of electricity imports and exports in total domestic power generation. This is our preferred specification. As per capita GDP, population, and capacity tend to be highly skewed to the right, we log transform these variables to keep our estimates from being unduly affected by outliers.

### 3.2.1 Instrumenting for reform activity

**Rationale.** To address potential endogeneity of reform issues, we construct an instrumental variable for domestic reform scores by using the average number of reforms implemented in surrounding countries. Researchers, such as Giuliano *et al.* (2013) and Acemoglu *et al.* (2019), have used similar IV approaches to estimate the effect of democracy on structural reforms and economic growth. For reforms in the power sector, Urpelainen *et al.* (2018) employ both

[5] Control variables are included to avoid omitted variable bias. Lagging those by fewer (or more) than three years, however, could induce bias, as their values might be influenced by past reforms (or influence future reform uptake). If this is the case, indirect reform effects would be absorbed in the coefficient of the control variables (or vice versa, the reform coefficient would measure an indirect impact of another variable).

a regional and a neighboring country IV. Given the highly contiguous dataset at hand, we prefer neighborhood as a reference, which allows us to exploit greater spatial variation within the IV itself. In the present context, the underlying rationale is that regional competition between governments for investment induces regulatory spillovers from one country to another. This occurs, because reforming one's power sector is often seen as the demonstration of a credible commitment to a stable institutional setup, which then sends a positive signal to investors and lenders (Gilardi *et al.*, 2006). Hence, when countries compete for outside financing, be it private or development finance, governments have an incentive to draw level with reform-implementing neighbors and to adopt similar institutional arrangements in order to attract more investment themselves. An alternative explanation for regulatory and policy spillover could be learning from neighbors' experiences (Becker and Davies, 2017; Gilardi and Wasserfallen, 2019).

**Constructing the IV.** When constructing our instrument, we define a country's neighbors as all those countries that either share a direct border with it or are located within a 400 sea-mile distance of it, based on data from the Correlates of War Direct Contiguity dataset (version 3.2). We then form the average of the reform scores across all neighbors in a given year to derive the instrument $NeighReforms$. The estimated values of a country's reform score, $\widehat{Reforms}$, which result from the first stage regression, are then used as the main independent variable in the second stage regression to derive the partial effect of reforms on the performance indicators.

**Relevance.** For validity, the first condition any instrument must satisfy is relevance. That is, the instrument must be sufficiently correlated with the endogenous variable of interest. Foster *et al.* (2017) identify geographic region as a particularly strong predictor of reform spread across countries, even before other country characteristics, such as income group or the size of the power system, which suggests the possibility of a domino or bandwagon effect of reform take-up within geographic regions. This spatial correlation is also reflected in the highly significant first-stage regression results displayed in Table A1 of the Appendix, which confirms the relevance of the instrument for predicting the endogenous regressor. Moreover, in all estimated model specifications, the null hypothesis of weak instruments can be rejected, as the F-statistic by far exceeds the critical value of 10 that is proposed by Staiger and Stock (1997).

**Exogeneity: Power trade.** The second necessary condition for IV-validity is exogeneity. This requires that there be no correlation between the instrument and the second stage error term; more specifically, reforms implemented in one country must not influence the performance outcomes in its neighbor, except by inducing reforms there. While instrument relevance can be tested, this exclusion restriction hinges on theoretical deliberations. One channel through which this condition could be violated is the interconnectedness of the power sectors. If a country increases its generation capacity by allowing for IPP participation and is, therefore, able to export more power to its neighbor, the effects of IPP-reform in one country have a direct spillover on the performance outcomes in another; hence, exogeneity would be violated. However, in such cases, the channel through which performance spillovers materialize is the power-trade relationship between the two countries, rather than reforms per se; thus, controlling for the share of electricity imports and exports can restore independence of the instrument conditional on these controls.[6]

**Exogeneity: Corruption spillovers.** Another possible threat to exogeneity is regional spillover in corruption control that is targeted at impeding power theft, fraud, or embezzlement of funds budgeted for infrastructure projects. The corruption literature finds that, unlike with corrupt behavior itself, anti-corruption activities indeed may spread from one country in a region to another (Becker *et al.*, 2009). Therefore, any simultaneity between corruption control and reform implementation could challenge IV exogeneity. Given that Imam *et al.* (2018) find less corruption to be associated with better performance for both our outcomes, we expect the direction of bias to be positive, i.e., the loss-reducing or access-improving effect would be overstated. Given that we do not find a significant correlation between corruption control and reforms as soon as we control for year- and country-fixed effects, we do not regard corruption as an issue here.

**Exogeneity: Residual risks.** Although we investigated several channels for spillover effects, one cannot fully rule out any risk of instrument endogeneity. There may be other unobserved impacts, such as the establishment of off-grid renewable energy providers in a country where reforms are already underway, that then spread business across the region. We consider this as a possible but negligible risk and see little cause for concern that reforms should affect efficiency or access in a neighboring country other than through inducing reforms.

### 3.2.2 Regional impacts of reform

**Regional differences.** Does the effect of reforms differ across regions? When analyzing the diffusion of reforms across developing countries, there appear to be regional differences that not only regard the speed of reform uptake but also concern the combination and sequencing of individual reform steps (Foster *et al.*, 2017; Urpelainen and Yang, 2019). Between regions, the countries with the highest rates of privatization and competition reforms tend to be located in Eastern Europe and Latin America. In Sub-Saharan African countries, competitive wholesale and retail markets are virtually non-existent, and power sectors remain largely bundled. South Asia has set a stronger focus on liberalizing the sector and opening it up for IPPs; but, as of 2013, retail competition also remains absent there. Moreover, unobserved regional heterogeneity—for example, institutional factors, culture, or common history—could mediate the effect of reforms on performance.

**Reforms-region interaction.** To capture these differences, we estimate an alternative specification of the above model with full controls, in which we interact the reform score with a region vector $Reforms_{it-3} \times Region_i$. The latter includes one dummy variable for each of the six World Bank regions in the sample, allowing us to estimate a distinct coefficient on the reform score for each region.

[6] Next to controlling for power imports and exports, like Urpelainen *et al.* (2018) we also excluded any observation with a combined imports-exports share above the 95th percentile. Results remained robust (Table A2 and Table A3). A placebo test on the IV assuming purely random reform allocation yields null-effects, as expected.

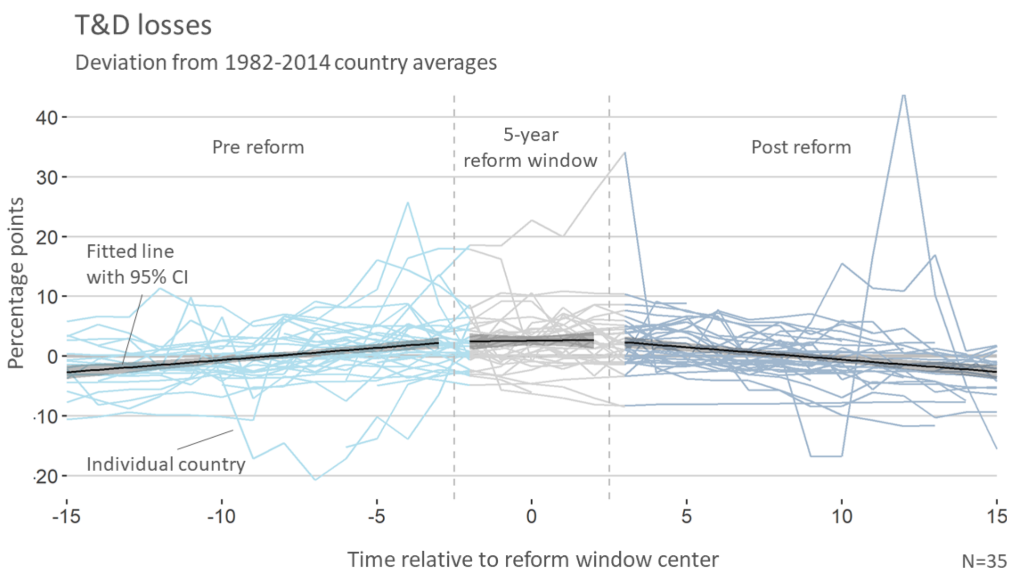
# 4. Results

For both outcomes, efficiency and access, we first present a visualization of the pre- and post-reform periods, then the OLS and IV estimates from the panel regressions, and finally, the regionally disaggregated reform effects. For efficiency, we study one indicator, T&D losses; for access, we explore two indicators, connection rates and per capita consumption. We discuss the robustness of our results below in Section 5.

## 4.1 Power sector efficiency

Visualization. In our descriptive trend analysis graph of T&D losses, shown in Figure 1, we observe an overall loss-increasing trend in the years prior to the reform window. This suggests that efficiency, on average, deteriorated in the 35 sample countries. This trend reverses during the post-reform period; the change is statistically significant.[7]

Figure 1. Trend analysis: T&D losses




OLS results. This observed trend break is reflected in the results of a preliminary least squares regression on our preferred model specification (Table 2, Model 1). The estimate suggests that each additional reform step is associated with a decrease in losses by 0.65 percentage points.

[7] To test the significance of the change in trends, we used a simple linear regression that is technically equivalent to non-parametric regression discontinuity design. However, as this is not applied in quasi-experimental setup, it cannot identify causality; it also does not include control variables.

The estimate is highly statistically significant. This finding aligns with the OLS estimations in both Erdogdu (2011) and Urpelainen *et al.* (2018).

Table 2. Regression results: Efficiency

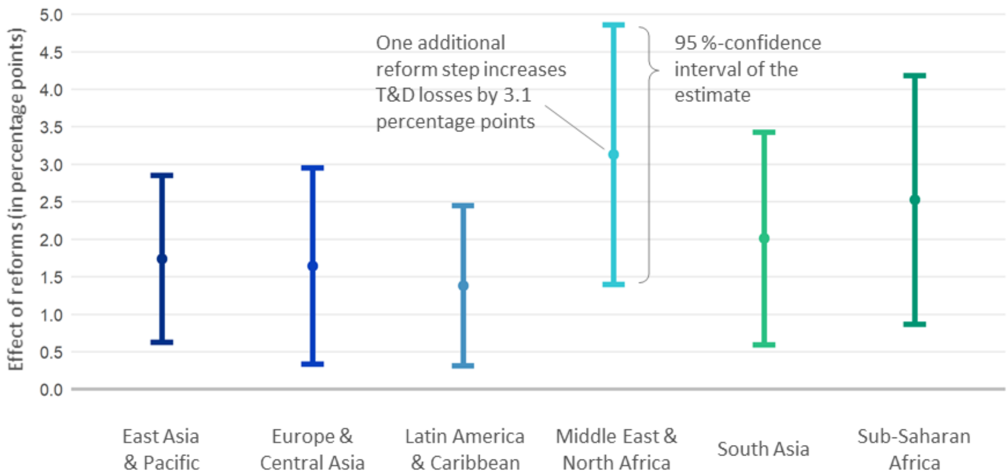
| | Dependent variable: T&D losses (%) | | |
|---|---|---|---|
| | OLS | IV | |
| Model: | (1) | (2) | (3) |
| Reforms $_{t-3}$ | -0.635*** | 1.003** | 0.770* |
| | (0.088) | (0.472) | (0.422) |
| ln(GDP p.c.) $_{t-3}$ | -7.444*** | -7.826*** | -7.091*** |
| | (1.083) | (1.038) | (1.163) |
| ln(Population) $_{t-3}$ | 5.134*** | 8.704*** | 7.962*** |
| | (1.702) | (2.184) | (1.982) |
| ln(Density) $_{t-3}$ | -0.471 | -1.744*** | -1.528** |
| | (0.471) | (0.67) | (0.612) |
| ln(Polity) $_{t-3}$ | 0.018 | -0.023 | 0.008 |
| | (0.045) | (0.051) | (0.047) |
| ln(Capacity p.c.) $_{t-3}$ | -0.511 | | -0.607 |
| | (0.743) | | (0.78) |
| Power imports $_{t-3}$ | 4.566*** | | 4.513*** |
| | (1.357) | | (1.368) |
| Power exports $_{t-3}$ | -5.404* | | -6.441* |
| | (3.207) | | (3.392) |
| Weak instruments | - | 0 | 0 |
| Wu-Hausman | - | 0.00025 | 0.00055 |
| Countries | 86 | 86 | 86 |
| Observations | 2181 | 2191 | 2181 |

Note: Robust standard errors in parentheses. All models include country and year fixed effects. Significance levels: * p < 0.1; ** p < 0.05; *** p < 0.01.

**IV results.** The 2SLS-IV results (Models 2 and 3) paint a starkly different picture. When accounting for the endogeneity of reform, the reforms coefficient flips signs, which suggests that reforms induce *higher* losses. The estimates are significant at the five- and ten-percent level, respectively; however, they turn out to be quite sensitive to assumptions, as we will discuss in Section 5. This result contrasts with a previous comparable study by Urpelainen *et al.* (2018), who find a robust loss-reducing effect of reforms. The discrepancy between their results and ours seems to be caused by the wider temporal and geographic coverage of the updated reform dataset used in our study.[8] It now includes reform data for regions where the previous study had assumed zero reforms, particularly in Africa and the Middle East.

Regional. We next include regional interaction terms in the IV model with full controls (Table A4). For each region, we plot the coefficient estimate on the reform variable and its corresponding 95%-confidence interval. As Figure 2 shows, in all regions, the loss-increasing effect of the reforms is statistically significant at the five-percent level. However, the size of the estimates varies greatly, with an impact that is two to three times greater in the MENA region than elsewhere. Yet, all six confidence intervals are large and overlap significantly, which implies that the effect varies rather strongly between and within the countries of a region, more strongly than the average effects themselves differ between regions. Moreover, the effects displayed are far larger than the average effect identified in the simple regression in column 2 of Table 2. This stems from the fact that, as the point estimates are now sub-group specific, so too are the country-fixed effects, which in turn affect the intercept and the slope in a linear model.

Figure 2. Effect of reforms on T&D losses across regions




[8] We can largely replicate these results based on then-available reform data by Erdogdu (2011) from 92 countries.

## 4.2 Electricity access

Visualization. The development of our two electricity access indicators, connection rates, and residential consumption during the pre- and post-reform periods are depicted in Figure 3 and Figure Figure 4, respectively. Both indicators improve quite steadily over time, with no statistically significant differences in levels or slopes before and after reform implementation. Given that both access indicators span only 26 years, we also analyze the trends 10 years before and after the reform window; however, the results remain unchanged.

Figure 3. Trend analysis: Power connections

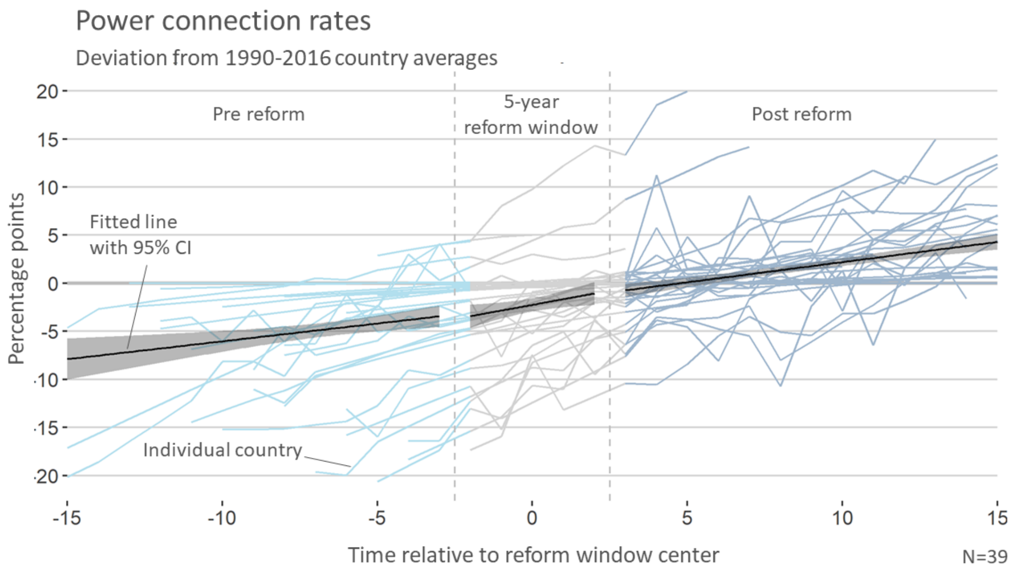
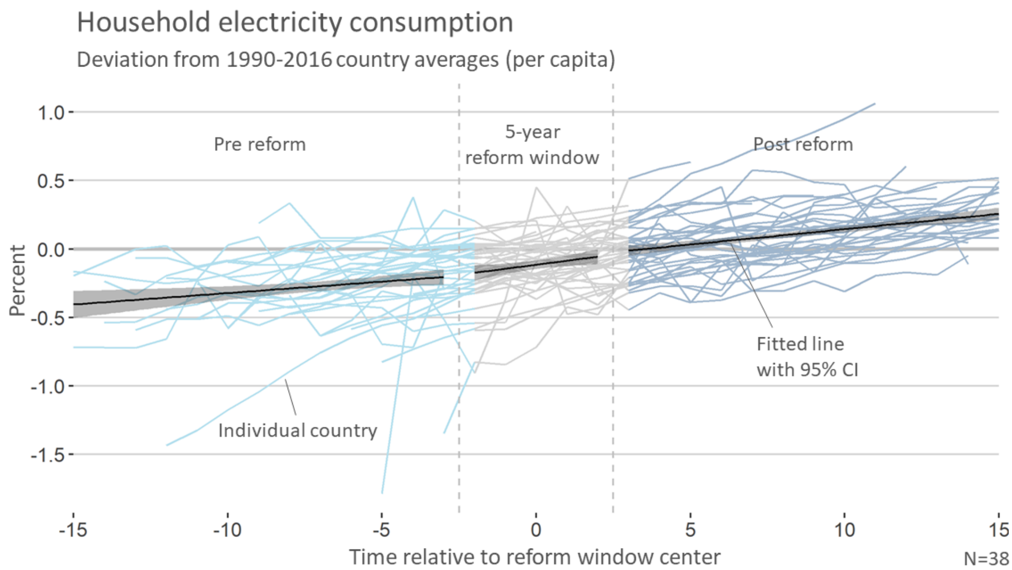



Figure 4. Trend analysis: Electricity consumption



**OLS results.** An uninstrumented, controlled regression of reforms on power connection rates yields no statistically significant relationship between the two (Table 3, Model 1). For electricity consumption (Table 3, Model 4), the reform coefficient is negative and highly statistically significant, which suggests that a reduction in consumption is a consequence of the reforms. Both of our OLS results are somewhat surprising, given the range of OLS studies that find a positive association between reforms and installed capacity as well as electricity generation (Jamasb *et al.* 2015; Urpelainen *et al.* 2018).

Table 3. Regression results: Access

| | Dependent variable: | | | | | |
|---|---|---|---|---|---|---|
| | Connection rates (%) | | | ln(Electricity consumption p.c.) | | |
| | OLS | IV | | OLS | IV | |
| Model: | (1) | (2) | (3) | (4) | (5) | (6) |
| Reforms $_{t-3}$ | 0.075 | 2.536*** | 2.503*** | -0.016*** | 0.081** | 0.078** |
| | (0.09) | (0.712) | (0.72) | (0.006) | (0.033) | (0.033) |
| ln(GDP p.c.) $_{t-3}$ | -0.223 | 0.58 | -0.263 | 0.336*** | 0.379*** | 0.341*** |
| | (0.719) | (0.694) | (0.712) | (0.049) | (0.046) | (0.048) |
| ln(Population) $_{t-3}$ | 10.318*** | 16.701*** | 15.114*** | 0.201*** | 0.400*** | 0.354*** |
| | (1.471) | (2.238) | (2.174) | (0.066) | (0.081) | (0.08) |
| ln(Density) $_{t-3}$ | 0.152** | 0.144** | 0.187*** | -0.007** | -0.008*** | -0.006* |
| | (0.06) | (0.062) | (0.066) | (0.003) | (0.003) | (0.003) |
| ln(Polity) $_{t-3}$ | -5.611*** | -8.526*** | -8.540*** | -0.204*** | -0.312*** | -0.310*** |
| | (0.568) | (1.103) | (1.101) | (0.03) | (0.052) | (0.052) |
| ln(Capacity p.c.) $_{t-3}$ | 2.862*** | | 2.003*** | 0.143*** | | 0.105*** |
| | (0.504) | | (0.544) | (0.027) | | (0.031) |
| Power imports $_{t-3}$ | 0.395** | | 0.311* | 0.011** | | 0.008 |
| | (0.177) | | (0.189) | (0.005) | | (0.006) |
| Power exports $_{t-3}$ | -4.534** | | -10.303*** | -0.011 | | -0.242** |
| | (2.161) | | (3.654) | (0.078) | | (0.117) |
| Weak instruments | - | 0 | 0 | - | 0 | 0 |
| Wu-Hausman | - | 0.00033 | 0.00035 | - | 0.00394 | 0.00477 |
| Countries | 107 | 107 | 107 | 104 | 104 | 104 |
| Observations | 2595 | 2605 | 2595 | 2550 | 2559 | 2550 |

Note: Robust standard errors in parentheses. All models include country and year fixed effects. Significance levels: * p < 0.1; ** p < 0.05; *** p < 0.01.

IV results. As in the case of T&D losses, our instrumented regression results differ greatly from the OLS estimates. The IV regressions suggest that reforms have a large positive and highly significant effect on connection rates (Table 3, Models 2 and 3). Each additional reform step is associated with more than a 2.5 percentage point increase in access to electricity. A full reform program, which covers all eight steps, would thereby increase connection rates by as much as 20 percentage points. A similarly impressive effect can be found in the instrumented regressions on electric power consumption (Table 3, Models 5 and 6), in which each additional reform leads to a more than seven percent higher consumption of electricity, an effect that is significant at the five percent level. A fully-fledged reform would increase consumption by around 62 percent. These results align with the direction of the effect, observed by Urpelainen et al. (2018), for a constitutive factor of improved electricity access, i.e., installed capacity.

Regional. Regional variation between our estimates is large (see Figure 5 and Figure 6). While in all regions but one the effect is statistically significant, it is much larger in South Asia than elsewhere. This is partially explained by particularly rapid electrification in Afghanistan, Bhutan, and Nepal. In those three countries, reform data reports that only a total of two reforms were introduced by 2013 (one of which being liberalization), which our results suggest have been particularly effective. Reforms appear to cause no further improvements in Eastern European and Central Asian countries, which make sense because vast parts of these regions already had nearly universal power coverage and high levels of power consumption prior to reforming. The large increase in power consumption in South Asia (34 percent per reform step) is relative to the quite low initial consumption levels in the region, averaging 40 kWh per capita in 1990. The two indicators show remarkably similar regional patterns, except in East Asia and the Pacific, where the effect on consumption is more pronounced. A possible driver of the particularly strong effect in Asian countries beyond our model is the surge in off-grid systems in rural and remote areas over the past decade. By 2016, over two thirds of global off-grid renewable capacity had been installed in Asia alone, followed by Sub-Saharan Africa with the second highest share (IRENA, 2018). Due to lack of temporally comprehensive data on installed off-grid capacity, we cannot control for this factor in our analysis.

Figure 5. Effect of reforms on power connection rates across regions

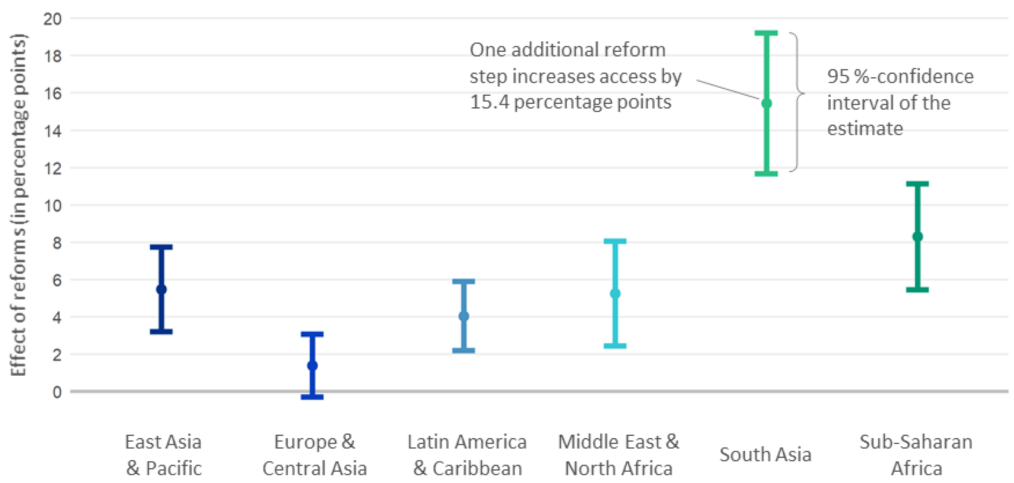
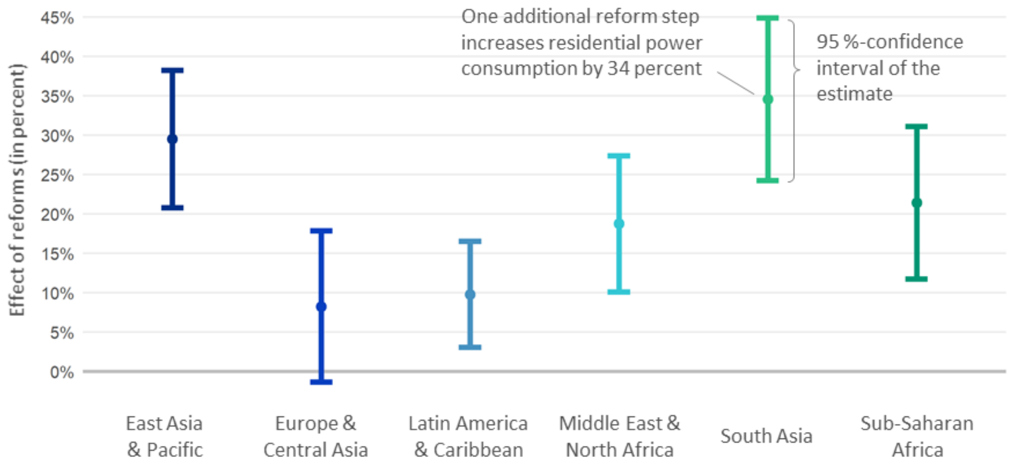


Figure 6. Effect of reforms on electricity consumption p.c. across regions




## 4.3 Endogeneity bias

The bias of least squares. The main motive for using an IV-identification strategy in this paper is policy endogeneity: the idea that performance in the power sector is likely to prompt reform, in which case a least squares estimation of the effect of reform would be biased. But what exactly is the underlying relationship between reform and our two outcomes?

Efficiency. A comparison of the OLS and IV regression results in Table 2 above shows that for our efficiency indicator, the OLS estimate is biased downward: the loss-reducing effect of reforms suggested by the OLS estimates turns into a loss-increasing effect in the IV models. However, keeping in mind the limited robustness of these estimates, we refrain from drawing any further inferences from this comparison.

Access. In the access regressions of Table 3 above, the bias of OLS goes in the same direction. At first sight, reforms appear to have a negative or null impact; but, when accounting for the endogeneity of reform, we can, in fact, identify a strong positive causal effect. One plausible interpretation of this apparent endogeneity bias is that problems in the power sector—such as incomplete access, high electricity cost, or insufficient power generation—trigger reforms in the first place. In other words, our findings are consistent with the hypothesis that "crises trigger reforms." Due to inertia, this poor performance continues into the post-reform era. Hence, in the presence of unmitigated endogeneity, this underlying negative correlation between low connection rates or low consumption levels and reform counteracts the true effect, such that the regression output understates the effectiveness of the reforms.

# 5. Robustness

We conducted a broad range of robustness tests, from which we find an interesting pattern: across the board, the results on access are impressively robust, while the results on losses are highly sensitive. All results are available in the Appendix.

Alternative model specification. First, we replace year-fixed effects by a linear time trend (Table A5). The coefficients for the two access indicators change slightly in magnitude but remain highly significant. The reform coefficient on losses, by contrast, becomes very small and insignificant. To test whether our chosen lag-duration drives our results, we additionally estimate models using one- to five-year lags. Again, the results for power connection rates and consumption are robust, but for losses, the effect becomes smaller and insignificant as the number of lags grows (Table A6).

Additional controls. Aside from the two main model specifications, we include further covariates that could influence outcomes (Table A7). Given the high levels of power theft in many countries, we additionally control for power connection rates in the T&D regressions. Although this shortens the observational period by five years, the estimates are qualitatively unchanged, though they become larger in size. Furthermore, we test whether the results are driven by countries with very high power losses; however, we find approximately the same effects after excluding Benin, Togo, Haiti, Iraq, and Libya from the analysis. In the access regressions, our results are robust against controlling for the rural population shares, which only reduces the size of the reform coefficient on connection rates by 0.5 percentage points. The same holds for electricity consumption, where the effect remains virtually unchanged. When controlling for electricity connection rates in the consumption regressions, the coefficient loses significance. Instead, we find a positive and highly significant coefficient on connection rate. A one percentage point increase in the population share connected to power coincides with 1.3 percent increase in power consumption. This suggests that higher official access rates might indeed translate into higher power use throughout society.

# 6. Concluding thoughts

Summary of results. This study uses 32 years of data from over 100 countries to study the impact of power sector reforms on two outcomes, industry efficiency and electricity access. To address the endogeneity of reform (“crisis triggers reforms”), we use reform activities in neighboring countries as instruments. We find a strong indication for reforms being beneficial to electricity access along two dimensions. A fully-fledged reform program, consisting of eight individual reform steps, increases power connection rates by 20 percentage points and per capita residential consumption by as much as 62 percent. This suggests that extensions in connectivity also coincide with higher power consumption. Although we cannot establish who ultimately consumes the additional power, it gives room for optimism that physical connections are not entirely offset by higher power prices or household connection charges. Regional variation in the effect size is substantial, with similar patterns for both indicators: the positive impact of reforms is particularly large in South Asia (both indicators), Sub-Saharan Africa (connection rates), and East Asia and the Pacific (residential consumption). No significant impact on both access indicators was found in Eastern Europe and Central Asia, where access represents a lesser challenge. For efficiency, our preferred specification suggests that reforms, in fact, lead to *higher* T&D losses, while there had been hope that reforms would reduce non-technical losses in particular. However, given the lack of robustness of this result and the conflicting evidence from earlier studies, we do not give this finding much weight. Yet, we consider it worth emphasizing that, in contrast to previous studies, we cannot find robust evidence to support the theory that reforms reduce losses.

Policy takeaways. Hence, we conclude that reform activity, taken as a composite, does not cure all problems in the electric power industry and that different types of issues might require different types of policies. This is particularly pertinent to T&D losses, given their predominantly non-technical nature, whose causes may be too deeply rooted in social issues to be solved merely within the electric power industry. Moreover, the effectiveness and suitability of reform is highly context-dependent and is likely affected by the interplay between country preconditions, the overall regulatory environment, and development dynamics. We do, however, find that power sector reforms greatly help spread electrification, one of the key ingredients for attaining major development goals in our time.

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# Appendix

Table A1. First stage results

| | Dependent variable: Reforms $_{t-3}$ | | | | | |
|---|---|---|---|---|---|---|
| | T&D Losses (%) | | Connection rates (%) | | ln(Electricity consumption p.c.) | |
| NeighReforms $_{t-3}$ | 0.284*** | 0.286*** | 0.269*** | 0.266*** | 0.280*** | 0.277*** |
| | (0.036) | (0.036) | (0.033) | (0.033) | (0.033) | (0.033) |
| ln(GDP p.c.) $_{t-3}$ | -0.174 | -0.234 | 0.113 | -0.076 | 0.083 | -0.149 |
| | (0.161) | (0.18) | (0.092) | (0.097) | (0.091) | (0.098) |
| ln(Population) $_{t-3}$ | -1.317*** | -1.256*** | -1.586*** | -1.547*** | -1.216*** | -1.211*** |
| | (0.339) | (0.342) | (0.265) | (0.266) | (0.261) | (0.261) |
| ln(Density) $_{t-3}$ | 0.648*** | 0.644*** | 1.256*** | 1.240*** | 1.168*** | 1.152*** |
| | (0.12) | (0.119) | (0.146) | (0.141) | (0.129) | (0.123) |
| ln(Polity) $_{t-3}$ | 0.011 | 0.007 | -0.009 | -0.01 | -0.009 | -0.009 |
| | (0.009) | (0.01) | (0.009) | (0.009) | (0.009) | (0.009) |
| ln(Capacity p.c.) $_{t-3}$ | | 0.032 | | 0.346*** | | 0.399*** |
| | | (0.138) | | (0.06) | | (0.061) |
| Power imports $_{t-3}$ | | -0.013 | | 0.024** | | 0.027** |
| | | (0.06) | | (0.012) | | (0.012) |
| Power exports $_{t-3}$ | | 0.478 | | 2.246*** | | 2.311*** |
| | | (0.494) | | (0.363) | | (0.368) |
| Observations | 2191 | 2181 | 2605 | 2595 | 2559 | 2550 |
| $R^2$ | 0.782 | 0.784 | 0.789 | 0.795 | 0.785 | 0.791 |
| Adjusted $R^2$ | 0.769 | 0.771 | 0.778 | 0.783 | 0.774 | 0.779 |
| F Statistic | 62.285*** | 61.287*** | 67.517*** | 67.941*** | 66.223*** | 66.721*** |

Note: Robust standard errors in parentheses. All models include country and year fixed effects. Significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A2. Excluding import-export ratio above the 95th percentile

| | Dependent variable: T&D losses (%) | | |
|---|---|---|---|
| | OLS | 2SLS | |
| Model: | 1 | 2 | 3 |
| Reforms t-3 | -0.599*** | 0.642 | 0.801* |
| | (0.087) | (0.394) | (0.41) |
| ln(GDP p.c.) t-3 | -6.757*** | -6.592*** | -6.409*** |
| | (1.095) | (1.005) | (1.187) |
| ln(Population) t-3 | 3.816** | 6.136*** | 6.279*** |
| | (1.674) | (1.862) | (1.937) |
| ln(Density) t-3 | -0.268 | -1.137** | -1.257** |
| | (0.471) | (0.58) | (0.599) |
| ln(Polity) t-3 | 0.059 | 0.04 | 0.052 |
| | (0.043) | (0.046) | (0.046) |
| ln(Capacity p.c.) t-3 | -0.029 | - | -0.165 |
| | (0.758) | | (0.791) |
| Power imports t-3 | 1.801 | - | 1.851 |
| | (2.947) | | (3.056) |
| Power exports t-3 | -6.980*** | - | -7.980** |
| | (2.644) | | (3.137) |
| Weak instruments | - | 0 | 0 |
| Wu-Hausman | - | 0.00115 | 0.00037 |
| Observations | 2054 | 2054 | 2054 |

Note: Robust standard errors in parentheses. All models include country and year fixed effects.
Significance levels: * p < 0.1; ** p < 0.05; *** p < 0.01.

Table A3. Excluding import-export ratio above the 95th percentile

| | Dependent variable: | | | | | |
|---|---|---|---|---|---|---|
| | Connection rates (%) | | | ln(Electricity consumption p.c.) | | |
| | OLS | IV | | OLS | IV | |
| Model: | 1 | 2 | 3 | 4 | 5 | 6 |
| Reforms t-3 | 0.199** | 2.288*** | 2.489*** | -0.016*** | 0.079** | 0.078** |
| | (0.09) | (0.729) | (0.766) | (0.006) | (0.033) | (0.033) |
| ln(GDP p.c.) t-3 | -0.389 | 0.444 | -0.509 | 0.336*** | 0.382*** | 0.341*** |
| | (0.688) | (0.674) | (0.668) | (0.049) | (0.046) | (0.048) |
| ln(Population) t-3 | 9.193*** | 14.899*** | 13.541*** | 0.201*** | 0.390*** | 0.354*** |
| | (1.517) | (2.225) | (2.185) | (0.066) | (0.08) | (0.08) |
| ln(Density) t-3 | 0.182*** | 0.171** | 0.219*** | -0.007** | -0.008*** | -0.006* |
| | (0.063) | (0.067) | (0.069) | (0.003) | (0.003) | (0.003) |
| ln(Polity) t-3 | -5.302*** | -7.842*** | -8.015*** | -0.204*** | -0.309*** | -0.310*** |
| | (0.571) | (1.113) | (1.131) | (0.03) | (0.051) | (0.052) |
| ln(Capacity p.c.) t-3 | 3.309*** | - | 2.532*** | 0.143*** | - | 0.105*** |
| | (0.543) | | (0.553) | (0.027) | | (0.031) |
| Power imports t-3 | 4.226*** | - | 6.527*** | 0.011** | - | 0.008 |
| | (1.353) | | (1.767) | (0.005) | | (0.006) |
| Power exports t-3 | -8.337** | - | -15.261*** | -0.011 | - | -0.242** |
| | (3.295) | | (5.349) | (0.078) | | (0.117) |
| Weak instruments | - | 0 | 0 | - | 0 | 0 |
| Wu-Hausman | - | 0.00308 | 0.00156 | - | 0.00495 | 0.00477 |
| Observations | 2472 | 2472 | 2472 | 2550 | 2550 | 2550 |

Note: Robust standard errors in parentheses. All models include country and year fixed effects. Significance levels: * p < 0.1; ** p < 0.05; *** p < 0.01.

Table A4. Region-interaction regression results

| | Dependent variable: | | |
|---|---|---|---|
| | T&D Losses (%) | Connection rates (%) | ln(Electricity consumption p.c.) |
| Reforms t-3 | 1.741*** | 5.491*** | 0.295*** |
| | (0.569) | (1.156) | (0.044) |
| x Eastern Europe & Central Asia | -0.093 | -4.094*** | -0.213*** |
| | (0.367) | (0.471) | (0.037) |
| x Latin America & Caribbean | -0.356 | -1.433*** | -0.197*** |
| | (0.204) | (0.402) | (0.021) |
| x Middle East & North Africa | 1.392 | -0.228 | -0.108*** |
| | (0.503) | (0.623) | (0.027) |
| x South Asia | 0.273 | 9.957*** | 0.05 |
| | (0.349) | (1.329) | (0.032) |
| x Sub-Saharan Africa | 0.786 | 2.812*** | -0.081*** |
| | (0.437) | (0.562) | (0.026) |
| ln(GDP p.c.) t-3 | -6.719*** | -0.48 | 0.290*** |
| | (2.328) | (2.526) | (0.181) |
| ln(Population) t-3 | 4.018* | -9.725*** | -0.053 |
| | (0.757) | (1.864) | (0.076) |
| ln(Density) t-3 | -2.003*** | -12.112*** | -0.680*** |
| | (0.054) | (0.086) | (0.004) |
| ln(Polity) t-3 | -0.021 | 0.299*** | -0.006 |
| | (1.03) | (0.638) | (0.028) |
| ln(Capacity p.c.) t-3 | -0.21 | 0.388 | 0.036 |
| | (1.38) | (0.207) | (0.006) |
| Power imports t-3 | 4.389*** | 0.036 | 0.0003 |
| | (3.776) | (4.145) | (0.143) |
| Power exports t-3 | -7.897** | -15.232*** | -0.376*** |
| | (0.569) | (1.156) | (0.044) |
| Weak instruments (Reform) | 0 | 0 | 0 |
| Weak instruments (Reform x E. Europe...) | 0 | 0 | 0 |
| Weak instruments (Reform x Latin...) | 0 | 0 | 0 |
| Weak instruments (Reform x Middle...) | 0 | 0 | 0 |
| Weak instruments (Reform x South...) | 0 | 0 | 0 |
| Weak instruments (Reform x Sub-Sah...) | 0 | 0 | 0 |
| Observations | 2,181 | 2,595 | 2,550 |

Note: Robust standard errors in parentheses. All models include the full set of control variables and country and year fixed effects. Reform variable instrumented with neighboring country reforms. Significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A5. Robustness: Time trend

| | Dependent variable: | | |
|---|---|---|---|
| | T&D Losses (%) | Connection rates (%) | ln(Electricity consumption p.c.) |
| Reforms $_{t-3}$ | 0.141 | 1.812*** | 0.074*** |
| | (0.275) | (0.481) | (0.025) |
| Year | 0.004 | 0.143 | 0.008 |
| | (0.088) | (0.117) | (0.005) |
| ln(GDP p.c.) $_{t-3}$ | -7.251*** | -0.433 | 0.325*** |
| | (1.064) | (0.681) | (0.045) |
| ln(Population) $_{t-3}$ | 7.347*** | 14.164*** | 0.368*** |
| | (1.865) | (1.825) | (0.073) |
| ln(Density) $_{t-3}$ | -1.058* | -7.598*** | -0.301*** |
| | (0.557) | (0.842) | (0.048) |
| ln(Polity) $_{t-3}$ | 0.033 | 0.203*** | -0.004 |
| | (0.044) | (0.061) | (0.003) |
| ln(Capacity p.c.) $_{t-3}$ | -0.508 | 2.347*** | 0.106*** |
| | (0.752) | (0.512) | (0.031) |
| Power imports $_{t-3}$ | 4.538*** | 0.330* | 0.007 |
| | (1.368) | (0.187) | (0.006) |
| Power exports $_{t-3}$ | -5.989* | -8.794*** | -0.242** |
| | (3.367) | (3.101) | (0.103) |
| Weak instruments | 0 | 0 | 0 |
| Wu-Hausman | 0.00355 | 0.00026 | 0.00071 |
| Observations | 2181 | 2595 | 2550 |

Note: Robust standard errors in parentheses. All models include the full set of control variables and country and year fixed effects. Reform variable instrumented with neighboring country reforms. Significance levels: * p < 0.1; ** p < 0.05; *** p < 0.01.

Table A6. Robustness: Different lag specifications

| | Dependent variable: T&D Losses | | | | |
|---|---|---|---|---|---|
| Lag: | 1 | 2 | 3 | 4 | 5 |
| Reforms $_{t-1}$ | 1.302*** | | | | |
| | (0.472) | | | | |
| Reforms $_{t-2}$ | | 1.260** | | | |
| | | (0.494) | | | |
| Reforms $_{t-3}$ | | | 0.770* | | |
| | | | (0.422) | | |
| Reforms $_{t-4}$ | | | | 0.628 | |
| | | | | (0.456) | |
| Reforms $_{t-5}$ | | | | | 0.368 |
| | | | | | (0.464) |
| Weak instruments | 0 | 0 | 0 | 0 | 0 |
| Wu-Hausman | 0.00002 | 0.00006 | 0.00055 | 0.00274 | 0.02147 |
| Observations | 2334 | 2259 | 2181 | 2101 | 2021 |

| | Dependent variable: Connection rates (%) | | | | |
|---|---|---|---|---|---|
| Lag: | 1 | 2 | 3 | 4 | 5 |
| Reforms $_{t-1}$ | 2.307*** | | | | |
| | (0.78) | | | | |
| Reforms $_{t-2}$ | | 2.435*** | | | |
| | | (0.744) | | | |
| Reforms $_{t-3}$ | | | 2.503*** | | |
| | | | (0.72) | | |
| Reforms $_{t-4}$ | | | | 2.445*** | |
| | | | | (0.688) | |
| Reforms $_{t-5}$ | | | | | 2.249*** |
| | | | | | (0.674) |
| Weak instruments | 0 | 0 | 0 | 0 | 0 |
| Wu-Hausman | 0.00263 | 0.00083 | 0.00035 | 0.00034 | 0.00066 |
| Observations | 2435 | 2516 | 2595 | 2570 | 2544 |

| | Dependent variable: ln(Electricity consumption p.c.) | | | | |
|---|---|---|---|---|---|
| Lag: | 1 | 2 | 3 | 4 | 5 |
| Reforms $_{t-1}$ | 0.077** | | | | |
| | (0.039) | | | | |
| Reforms $_{t-2}$ | | 0.095** | | | |
| | | (0.039) | | | |
| Reforms $_{t-3}$ | | | 0.078** | | |
| | | | (0.033) | | |
| Reforms $_{t-4}$ | | | | 0.075** | |
| | | | | (0.033) | |
| Reforms $_{t-5}$ | | | | | 0.051* |
| | | | | | (0.026) |
| Weak instruments | 0 | 0 | 0 | 0 | 0 |
| Wu-Hausman | 0.01937 | 0.00345 | 0.00477 | 0.00567 | 0.01401 |
| Observations | 2390 | 2471 | 2550 | 2528 | 2504 |

Note: Robust standard errors in parentheses. All models include the full set of control variables and country and year fixed effects. Reform variable instrumented with neighboring country reforms. Significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A7. Additional controls

| | Dependent variable: | | | | |
|---|---|---|---|---|---|
| | T&D Losses (%) | | Connection rates (%) | ln(Electricity consumption p.c.) | |
| Model: | 1 | 2 | 3 | 4 | 5 |
| Reforms $_{t-3}$ | 1.088* | 0.872** | 2.042*** | 0.074** | 0.064 |
| | (0.613) | (0.404) | (0.683) | (0.035) | (0.043) |
| ln(GDP p.c.) $_{t-3}$ | -6.126*** | -4.634*** | -1.654** | 0.326*** | 0.321*** |
| | (1.651) | (0.831) | (0.708) | (0.049) | (0.049) |
| ln(Population) $_{t-3}$ | 8.417*** | 7.051*** | 10.995*** | 0.319*** | 0.347*** |
| | (3.005) | (1.572) | (2.053) | (0.089) | (0.101) |
| Connection rates $_{t-3}$ | 0.085** | - | - | - | 0.013*** |
| | (0.038) | | | | (0.001) |
| Rural share $_{t-3}$ | - | - | -0.452*** | -0.004 | - |
| | | | (0.063) | (0.003) | |
| ln(Density) $_{t-3}$ | -1.51 | -1.609*** | -6.073*** | -0.287*** | -0.271*** |
| | (1.049) | (0.538) | (1.041) | (0.06) | (0.072) |
| ln(Polity) $_{t-3}$ | -0.076 | -0.039 | 0.167*** | -0.006** | -0.008** |
| | (0.082) | (0.041) | (0.062) | (0.003) | (0.004) |
| ln(Capacity p.c.) $_{t-3}$ | -1.231 | -0.714 | 1.711*** | 0.103*** | 0.073** |
| | (1.011) | (0.704) | (0.506) | (0.031) | (0.029) |
| Power imports $_{t-3}$ | 4.661*** | 2.838 | 0.248 | 0.007 | 0.013 |
| | (1.388) | (1.736) | (0.165) | (0.006) | (0.012) |
| Power exports $_{t-3}$ | -15.612*** | -7.138** | -8.300** | -0.205* | -0.142 |
| | (5.74) | (3.398) | (3.374) | (0.117) | (0.123) |
| Weak instruments | 0 | 0 | 0 | 0 | 0 |
| Wu-Hausman | 0.00564 | 0.00926 | 0.00279 | 0.00977 | 0.06912 |
| Observations | 1688 | 1609 | 2589 | 2544 | 2276 |

Note: Robust standard errors in parentheses. All models include country and year fixed effects. Models 1 and 5 control for connection rates. Model 2 excludes countries with high power losses: Benin, Haiti, Iraq, Libya and Togo. Models 3 and 4 additionally control for share of rural population. Reform variable instrumented with neighboring country reforms.

Significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A8. Descriptive statistics

| Variable | N | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|---|
| T&D Losses (% of gen.) | 2,658 | 16.055 | 10.593 | 0.037 | 88.024 |
| Connection rate (% of pop.) | 3,357 | 66.592 | 35.744 | 0.01 | 100 |
| ln(Electricity consumption p.c.) | 3,252 | 5.218 | 1.705 | -0.38 | 9.039 |
| Reforms $_{t-3}$ | 3,755 | 1.985 | 2.437 | 0 | 8 |
| Neighbor reforms $_{t-3}$ | 3,755 | 2.225 | 2.055 | 0 | 7.5 |
| ln(GDP p.c.) $_{t-3}$ | 3,569 | 7.751 | 1.286 | 4.88 | 11.485 |
| ln(Population) $_{t-3}$ | 3,750 | 15.789 | 1.793 | 11.107 | 21.029 |
| Population density $_{t-3}$ | 3,750 | 0.151 | 0.542 | 0.001 | 7.637 |
| Polity $_{t-3}$ | 3,052 | 0.979 | 6.707 | -10 | 10 |
| ln(Installed capacity p.c. $_{t-3}$ ) | 3,750 | -1.758 | 1.649 | -7.397 | 1.562 |
| Electricity imports (%) $_{t-3}$ | 3,755 | 0.207 | 1.305 | 0 | 37 |
| Electricity exports (%) $_{t-3}$ | 3,755 | 0.048 | 0.145 | 0 | 0.913 |

Table A9. List of countries in sample (by region)

| | | | |
|---|---|---|---|
| East Asia & Pacific | Tajikistan | Guatemala | Lesotho |
| 11 | Turkmenistan | Guyana | Liberia |
| Cambodia | Ukraine | Haiti | Madagascar |
| China | Uzbekistan | Honduras | Malawi |
| Fiji | Middle East & North Africa | Jamaica | Mali |
| Indonesia | 13 | Nicaragua | Mauritania |
| Malaysia | Algeria | Panama | Mauritius |
| Mongolia | Bahrain | Paraguay | Mozambique |
| Papua New Guinea | Djibouti | Peru | Namibia |
| Philippines | Iraq | Suriname | Niger |
| Singapore | Jordan | Trinidad and Tobago | Nigeria |
| Thailand | Kuwait | Uruguay | Rwanda |
| Vietnam | Lebanon | Sub-Saharan Africa | Senegal |
| East. Europe & Central Asia | Libya | 37 | Sierra Leone |
| 19 | Morocco | Angola | South Africa |
| Albania | Oman | Benin | Sudan |
| Armenia | Qatar | Botswana | Tanzania |
| Azerbaijan | Saudi Arabia | Burkina Faso | Togo |
| Belarus | Tunisia | Burundi | Uganda |
| Bulgaria | Latin America & Caribbean | Cameroon | Zambia |
| Croatia | 21 | Central African Republic | Zimbabwe |
| Cyprus | Argentina | Chad | South Asia |
| Georgia | Bolivia | Equatorial Guinea | 7 |
| Kazakhstan | Brazil | Eritrea | Afghanistan |
| Kosovo | Colombia | Ethiopia | Bangladesh |
| Latvia | Costa Rica | Gabon | Bhutan |
| Lithuania | Cuba | Ghana | India |
| Moldova | Dominican Republic | Guinea | Nepal |
| Montenegro | Ecuador | Guinea-Bissau | Pakistan |
| Romania | El Salvador | Kenya | Sri Lanka |