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Reforming the electric power industry in developing economies 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.

1. Introduction

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).

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.

Two particularly pressing problems in developing countries that are

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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 and its promotion is stipulated by the Sustainable Development Goal number seven. 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 assesses the impact of power sector reforms in developing economies using regression analysis based on panel data on 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.

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, by Caselli and Reynaud (2019) instrumenting for fiscal reforms, and by Sen and Vollebergh (2018) who instrument for carbon taxes on energy use. These four papers all use policies or reforms in nearby countries to instrument for domestic reform activity.

[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.

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 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, we use a new dataset with reform data for 142 countries which allows us to reassess the findings of a previous study that assumed no reform activity for around 20 of those and extend prior studies by at least three years of additional data. Finally, while previous studies analyzed outcomes either on a regional or global scale, we provide a regionally disaggregated analysis, using reform-region interaction effects. We also provide a new set of visualizations and a range of robustness tests.

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 seem to be 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.

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

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.

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).

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.

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 in many cases (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.

The present study builds on previous research and extends it by studying electricity access outcomes, by using a recent, more extensive dataset and by providing a regionally disaggregated analysis.

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

Our empirical analysis is based on an unbalanced panel of annual country-level observations from 1982 to 2016 covering 108 countries. Table 1 shows the regional averages of each of our three performance indicators and of the reform scores. The appendix (Tables A8 and A9) provide additional descriptive statistics.

Data on *T&D losses* comes from the World Bank's World Development Indicators (WDI) and covers 86 countries between 1960 and 2014. Losses are expressed as a share of total generation and capture both technical and non-technical losses. They range from ten to 25 percent in low-income countries and reach up to 60 percent in a few cases, compared to around six percent in industrialized countries. We prefer T&D losses over other measures of efficiency, such as outages, capacity utilization, and reserve margins. Data on outages is poor; utilization and reserve margins are difficult to interpret: they might be the result of recent investment, an often desirable outcome. 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).

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) for 107 countries.[2] This rate is measured as the share of the total population that had access to a source of electricity The spread in electricity coverage in those countries is ample, ranging from below 20 to above 90 percent.

Electricity consumption by households between 1990 and 2016 is obtained from the United Nations Statistics Division for 104 countries. We use the log of residential consumption per capita. As of 2016, power consumption was well above 1000 kWh in industrialized countries, but only at two-digit or low three-digit levels in most developing nations.

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

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

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	0.0	3.8
East. Europe & Central Asia[a]	13	7	100	100	673	983	0.0	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	0.0	3.9
Sub-Saharan Africa	20	13	17	42	75	154	0.0	3.3

[a] Data for years prior to 1991 contain average values from the former Soviet Union.

Yang (2018), building on Erdogdu (2011). 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). Referring to *de jure* enactment, the data 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 we cover had, on average, implemented four out of eight reforms, most ranging between three and seven.

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. 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 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.

In addition, we control for variables reflecting countries' economic, demographic, and political characteristics, and its power system. 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. Installed electricity generation capacity per capita and electricity imports and exports as a fraction of domestic generation was taken from the Energy Information Administration. GDP, population and capacity are taken in logs.

3.2. Identification

Our strategy for identifying the effect of power sector reforms on performance is informed by the presumption that the implementation of 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 to 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 α_i and δ_i as well as year-fixed effects, γ_t and μ_t. β_1 represents the main parameter of interest, while β_0 and θ_0 are constant terms. ε_{it} and π_{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.[4] We choose this lag duration for two reasons: first, to reflect the fact that de facto implementation of reforms is often delayed by several years Foster et al. (2017) and second, to exploit electricity access data up to 2016.

We estimate one model with a parsimonious set of macro-level controls, that is, a country's per capita GDP, 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, that is the per capita installed generation capacity as well as the share of electricity imports and exports relative to total domestic power generation. This is our preferred specification. Characteristics of the power sector affect performance outcomes, but they can also be outcomes of reform activity themselves. Excluding them could induce omitted variable bias; at the same time, they may also affect reform uptake.[5] We, therefore, split control variables and show both parsimonious and full control IV regressions.

3.2.1. Instrumenting for reform activity

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. Similar approaches have found application in other areas. Persson and Tabellini

[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).

[4] Control variables are included to avoid omitted variable bias. Using shorter (or longer) lags than for the reform variable, 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).

[5] As one reviewer pointed out, power exports and imports could be so-called bad controls (Deuchert and Huber, 2017) if their current levels have been affected by instrument assignment, that is if domestic power trade is a result of reform in neighboring countries. Hence, we face a tradeoff between bias from omitted variables and bad controls.

(2009) proxy for domestic democratic capital through democracy in neighboring countries; Giuliano et al. (2013) use democracy in countries that are political allies and Acemoglu et al. (2019) rely on regional democratization waves as an instrument for democracy; Caselli and Reynaud (2019) instrument for the adoption of fiscal rules using fiscal reforms in neighboring countries. For reforms in the power sector, Urpelainen et al. (2018) employ both 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).

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.[6]

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).

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.[7]

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. (2019) 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.

Although we investigated several channels for spillover effects, one cannot fully rule out any risk of instrument endogeneity. Power trade might not only impact performance but can also be a consequence of prior reform activity in neighboring countries, which would give rise to the issue of bad controls discussed earlier. Moreover, 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. A more substantial threat to our identification strategy would be simultaneity of reform spread and regional electrification programs. If this was the case, any effect identified would likely capture the combined impact of these two policies. In absence of a comprehensive policy database, however, controlling for the electrification programs remains unfeasible.

3.2.2. Regional impacts of reform

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.

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] We device a twofold aggregation of reform steps: reforms are first aggregated at the country level, then, regional averages are formed. This may inevitably exacerbate the issue of blurring differences between countries' uptake, combination and implementation of reforms mentioned in Section 3.1.

[7] 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 (and 90th) percentile. Results remained robust (Table A2 and Table A3). Additionally, we dropped observations where import and export shares were above 20 (or 15) percent each, with no change in results. Moreover, a placebo test on the IV assuming purely random reform allocation yields null-effects, as expected.

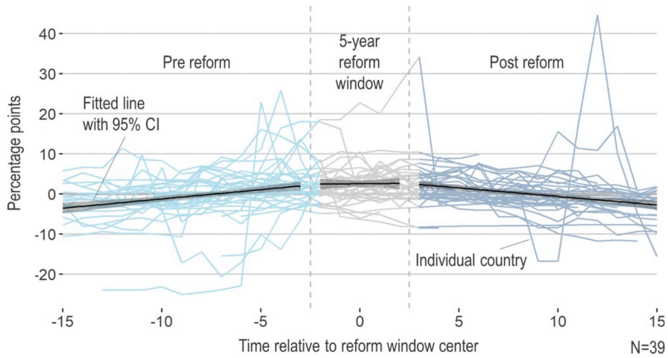

Fig. 1. Trend analysis: T&D losses
Note: Fig. 1 above shows the development of T&D losses for 35 countries. For each country, deviation from 1982-2014 averages is plotted over time relative to a five-year reform window.

4. Results

For both outcomes, efficiency and access, we first present a visualization of the pre- and post-reform periods for those 39 countries that feature a concentrated reform period of at least five reforms during a five-year window. We then present the OLS and IV estimates from the panel regressions (using the entire sample), 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

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.[8] 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.

In our descriptive trend analysis graph of T&D losses, shown in Fig. 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.[9]

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

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.[10] It now uses updated reform data where the previous study had assumed zero reforms and includes more developing countries, particularly from Africa and the Middle East, where some of the highest losses can be observed. This lack of data could have led the previous study to overestimate the effectiveness of reforms.

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 Fig. 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, country specific effects and control variables, representing the intercept in our linear model, now absorb higher (lower) shares of the variation in the data points and thereby compensate for higher sub-group specific point estimates.

Table 2
Regression results: Efficiency.

	Dependent variable: T&D losses (%)		
	OLS	IV	
Model:	(1)	(2)	(3)
Reforms $_{t-3}$	−0.635*** (0.088)	1.003** (0.472)	0.770* (0.422)
ln(GDP p.c.) $_{t-3}$	−7.444*** (1.083)	−7.826*** (1.038)	−7.091*** (1.163)
ln(Population) $_{t-3}$	5.134*** (1.702)	8.704*** (2.184)	7.962*** (1.982)
ln(Density) $_{t-3}$	−0.471 (0.471)	−1.744*** (0.67)	−1.528** (0.612)
ln(Polity) $_{t-3}$	0.018 (0.045)	−0.023 (0.051)	0.008 (0.047)
ln(Capacity p.c.) $_{t-3}$	−0.511 (0.743)		−0.607 (0.78)
Power imports $_{t-3}$	4.566*** (1.357)		4.513*** (1.368)
Power exports $_{t-3}$	−5.404* (3.207)		−6.441* (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: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

[8] 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.

[9] 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.

[10] We can largely replicate these earlier results when using then-available reform data by Erdogdu (2011) from 92 countries with our model.

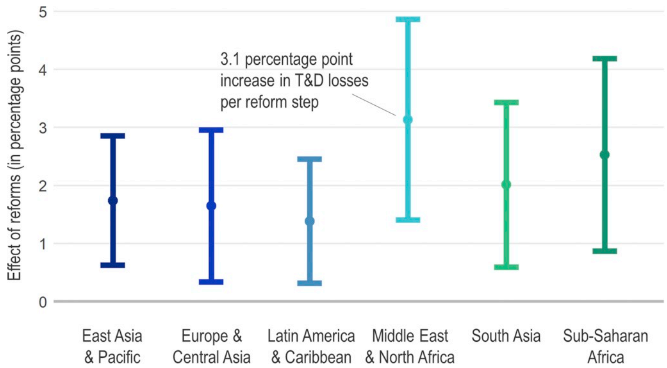

Fig. 2. Effect of reforms on T&D losses across regions
Note: Fig. 2 depicts the effect of one additional reform step on T&D losses for each region. Estimates are shown as points; whiskers represent the corresponding 95 %-confidence intervals.

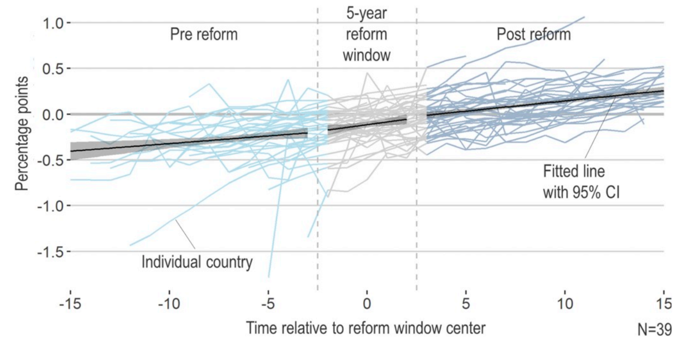

Fig. 4. Trend analysis: Electricity consumption
Note: Figs. 3 and 4 above show trends in connection rates and household electricity consumption per capita for 39 and 38 countries, respectively. For each country, deviation from 1990-2016 averages is plotted over time relative to a five-year reform window.

4.2. Electricity access

The development of our two electricity access indicators, connection rates, and residential consumption during the pre- and post-reform periods are depicted in Fig. 3 and Fig. 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.

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. 2017; Urpelainen et al. 2018).

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.

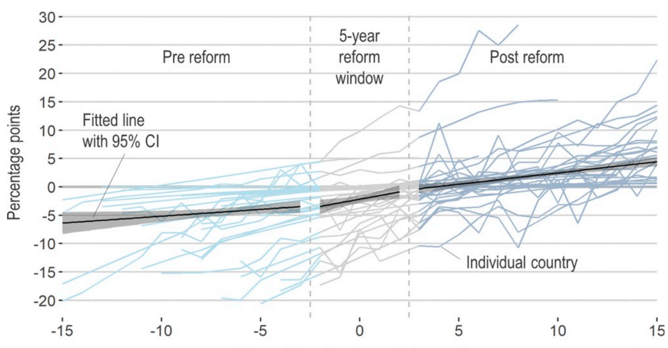

Fig. 3. Trend analysis: Power connections.

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 variation between our estimates is large (see Fig. 5 and Fig. 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 progress in Afghanistan, Bangladesh, Bhutan, and Nepal (WDI, 2018). In the latter two countries, only a total of two reforms had been introduced by 2013 and three in the case of Afghanistan. Our results suggest that those reforms (one of which being liberalization) have been particularly effective.[11] 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 low initial residential consumption 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). Among the countries that have substantially increased electricity access through off-grid electrification are Afghanistan, Bangladesh, Bhutan and Nepal (World Bank, 2018, 2019; Qehaja et al. 2019). Due to lack of temporally comprehensive data on installed off-grid capacity, we cannot control for this factor in our analysis.

4.3. Endogeneity bias

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?

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

[11] This finding somewhat contradicts Jamasb et al. (2017) who find reforms to have been effective in Latin America but less so in South Asia. However, the authors only consider studies on Indian rural electrification programs and power sector reforms in one Indian state and, hence, results are not directly comparable.

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 $_{t\text{-}3}$	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.) $_{t\text{-}3}$	−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) $_{t\text{-}3}$	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) $_{t\text{-}3}$	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) $_{t\text{-}3}$	−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.) $_{t\text{-}3}$	2.862***		2.003***	0.143***		0.105***
	(0.504)		(0.544)	(0.027)		(0.031)
Power imports $_{t\text{-}3}$	0.395**		0.311*	0.011**		0.008
	(0.177)		(0.189)	(0.005)		(0.006)
Power exports $_{t\text{-}3}$	−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.

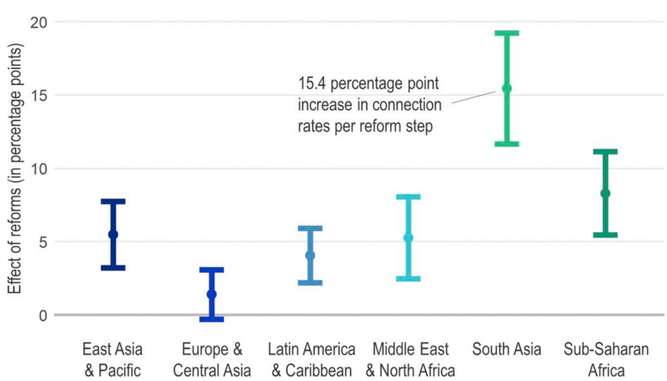

Fig. 5. Effect of reforms on power connection rates across regions.

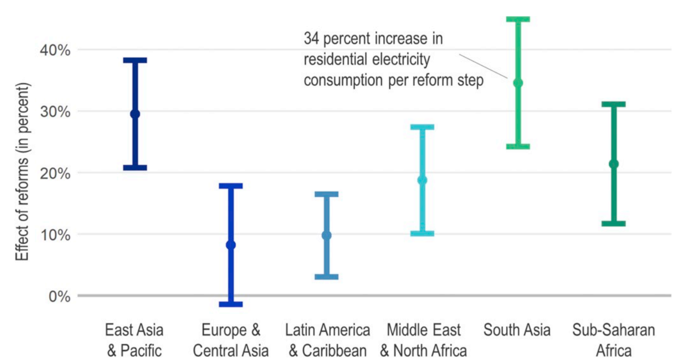

Fig. 6. Effect of reforms on electricity consumption p.c. across regions
Note: The above graphs depict the effect of one additional reform step on connection rates (Fig. 5) and electricity consumption (Fig. 6) for each region. Estimates are shown as points; whiskers represent the corresponding 95 %-confidence intervals.

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.

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.

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).

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. Conclusion and policy implications

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.

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 and quality of governance 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.

Declaration of competing interest

Both others declare no conflict of interest.

CRediT authorship contribution statement

Andrea Dertinger: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing - original draft. **Lion Hirth:** Supervision, Writing - review & editing, Visualization, Methodology, Conceptualization.

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*** (0.036)	0.286*** (0.036)	0.269*** (0.033)	0.266*** (0.033)	0.280*** (0.033)	0.277*** (0.033)
ln(GDP p.c.) $_{t-3}$	−0.174 (0.161)	−0.234 (0.18)	0.113 (0.092)	−0.076 (0.097)	0.083 (0.091)	−0.149 (0.098)
ln(Population) $_{t-3}$	−1.317*** (0.339)	−1.256*** (0.342)	−1.586*** (0.265)	−1.547*** (0.266)	−1.216*** (0.261)	−1.211*** (0.261)
ln(Density) $_{t-3}$	0.648*** (0.12)	0.644*** (0.119)	1.256*** (0.146)	1.240*** (0.141)	1.168*** (0.129)	1.152*** (0.123)
ln(Polity) $_{t-3}$	0.011 (0.009)	0.007 (0.01)	−0.009 (0.009)	−0.01 (0.009)	−0.009 (0.009)	−0.009 (0.009)
ln(Capacity p.c.) $_{t-3}$		0.032 (0.138)		0.346*** (0.06)		0.399*** (0.061)

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Table A1 (*continued*)

	Dependent variable: Reforms $_{t-3}$					
	T&D Losses (%)		Connection rates (%)		ln(Electricity consumption p.c.)	
Power imports $_{t-3}$		−0.013 (0.06)		0.024** (0.012)		0.027** (0.012)
Power exports $_{t-3}$		0.478 (0.494)		2.246*** (0.363)		2.311*** (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*** (0.087)	0.642 (0.394)	0.801* (0.41)
ln(GDP p.c.) t-3	−6.757*** (1.095)	−6.592*** (1.005)	−6.409*** (1.187)
ln(Population) t-3	3.816** (1.674)	6.136*** (1.862)	6.279*** (1.937)
ln(Density) t-3	−0.268 (0.471)	−1.137** (0.58)	−1.257** (0.599)
ln(Polity) t-3	0.059 (0.043)	0.04 (0.046)	0.052 (0.046)
ln(Capacity p.c.) t-3	−0.029 (0.758)		−0.165 (0.791)
Power imports t-3	1.801 (2.947)		1.851 (3.056)
Power exports t-3	−6.980*** (2.644)		−7.980** (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** (0.09)	2.288*** (0.729)	2.489*** (0.766)	−0.016*** (0.006)	0.079** (0.033)	0.078** (0.033)
ln(GDP p.c.) t-3	−0.389 (0.688)	0.444 (0.674)	−0.509 (0.668)	0.336*** (0.049)	0.382*** (0.046)	0.341*** (0.048)
ln(Population) t-3	9.193*** (1.517)	14.899*** (2.225)	13.541*** (2.185)	0.201*** (0.066)	0.390*** (0.08)	0.354*** (0.08)

(*continued on next page*)

Table A3 (*continued*)

	Dependent variable:					
	Connection rates (%)			ln(Electricity consumption p.c.)		
	OLS	IV		OLS	IV	
Model:	(1)	(2)	(3)	(4)	(5)	(6)
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 (Baseline: East Asia & Pacific)	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-Baseline)	0	0	0
Weak IV (Reform x E. Europe …)	0	0	0
Weak IV (Reform x Latin …)	0	0	0
Weak IV (Reform x Middle …)	0	0	0
Weak IV (Reform x South …)	0	0	0
Weak IV (Reform x Sub-Sah …)	0	0	0
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 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 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)

(continued on next page)

Table A6 (*continued*)

	Dependent variable: T&D Losses				
Lag:	1	2	3	4	5
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.)	2658	16.055	10.593	0.037	88.024
Connection rate (% of pop.)	3357	66.592	35.744	0.01	100
ln(Electricity consumption p.c.)	3252	5.218	1.705	−0.38	9.039
Reforms $_{t-3}$	3755	1.985	2.437	0	8
Neighbor reforms $_{t-3}$	3755	2.225	2.055	0	7.5
ln(GDP p.c.) $_{t-3}$	3569	7.751	1.286	4.88	11.485
ln(Population) $_{t-3}$	3750	15.789	1.793	11.107	21.029
Population density $_{t-3}$	3750	0.151	0.542	0.001	7.637
Polity $_{t-3}$	3052	0.979	6.707	−10	10
ln(Installed capacity p.c. $_{t-3}$)	3750	−1.758	1.649	−7.397	1.562
Electricity imports (%) $_{t-3}$	3755	0.207	1.305	0	37
Electricity exports (%) $_{t-3}$	3755	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

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