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A global analysis of progress in household electrification

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ABSTRACT

Universal electricity access is an important element of the United Nations Sustainable Development Goals, and global efforts to monitor progress in electrification have recently escalated. To inform these efforts, we describe a new database of total, rural, and urban electrification rates across the world. Using transparent coding criteria and decades of data, going back to the 1960s for many countries, from nationally representative surveys and official reports from 124 non-OECD countries, we uncover evidence for rapid progress in household electrification relative to earlier estimates. Our comprehensive and freely available database offers a solid baseline for tracking progress in household electrification across the world. We confirm a robust association between per capita income and household electrification, and identify population density and urbanization as additional key drivers.

1. Introduction

The United Nations Sustainable Development Goal (SDG) #7 strives to "ensure access to affordable, reliable, sustainable and modern energy for all," as a large body of literature suggests that access to a reliable an affordable supply of electricity and clean cooking fuels can contribute to healthier, more convenient, and more productive lives (Dinkelman, 2011; Barnes, 2014; Greenstone, 2014; Aklin et al., 2016). To support progress toward the energy access SDG, the World Bank has established a Global Tracking Framework (GTF) that measures progress in energy access over time (World Bank, 2017). The GTF is a unified set of metrics toward meeting the clean energy access SDG, with progress in electrification playing a central role.

While the GTF itself is a major achievement in measuring progress toward universal electricity access, it does not solve the problem of establishing a reliable historical baseline for national electrification rates around the world. The fundamental barrier to the robust tracking of progress in electrification is the lack of a good baseline, as the quality of historical data on rural electrification remains poor. Existing datasets on national electricity rates by the World Bank and the International Energy Agency (IEA) (World Bank, 2017; IEA, 2016) are not only incomplete, but are only available for the post-1990 period and include values that are based on simulation or interpolation (see Section 2). Assessing progress toward universal electricity access is greatly complicated by the lack of high-quality data on historical rates of progress by different countries. Historical data on changes in total and urban electrification would allow policymakers to compare their progress with previous rural electrification efforts and learn from past successes and failures.

To address this challenge, we describe a new database of total, rural, and urban electrification rates across the world.[1] With decades of data based on nationally representative surveys and official reports from 124 countries outside the OECD and post-communist world, we present the largest and most detailed dataset on electrification to this date. The dataset is based on transparent coding criteria, does not contain any information that relies on simulations or interpolations, and includes observations for the pre–1990 period (our dataset covers the period 1949-2015; see Section 2). We use the database to offer updated estimates on progress in electrification across the world and link this progress to country characteristics from income per capita to population density, urbanization, and natural resource rents. The fully documented data are freely available for non-commercial use to any interested users, and the sources for every data point are described in full in the replication archive.

We find evidence of rapid progress in total and rural electrification across the world. Our estimates suggest that past numbers, such as the

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[1] Collecting data on both urban and rural electrification rates are necessary since the urban rate alone does not always convey the correct picture. For instance, the total electrification rate for Chile in 1960 was 70.6%, a fairly high rate for this period. But this was achieved mainly through urban electrification (86.3%) while rural electrification still languished (23.9%).

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GTF estimates, have substantially underestimated progress in electrification over the past decades. This result is robust to excluding our pre-1990 observations, excluding outliers, and various estimation strategies, including fractional logistic regressions. Indeed, nation-level trends in electrification rates are mostly linear over time. Even Sub-Saharan Africa, where electrification rates are usually much worse than any other region, performs better than previous estimates. These results show that the World Bank's interpolation approach understates nation-level progress in household electrification.

We also confirm the robust link between electrification rates and per capita income, and show that high population densities and urbanization go a long way toward explaining why some countries have achieved high electrification rates even under low incomes per capita. In contrast, democratic political institutions and natural resource rents do not explain overperformance in progress toward universal electrification.

2. Methodology and data

Our sample includes non-OECD countries with a population of at least 300,000 and that have reliable electrification data. This means that wealthy western European nations and post-Soviet countries with a universal electrification rate early on are not part of our sample. That also applies to conflict-ridden or completely closed political systems like Afghanistan, Iraq, and North Korea. In effect, our sample comprises of 124 countries spanning 15 regions (see Table S1, which contains the coverage for our data and the World Bank's).

We followed three different rules when compiling the data. First, we defined national/urban/rural electrification rates with respect to households, i.e., the proportion of total/rural/urban households within a country that had access to electricity. This was the easiest way to ensure consistency across the sample. However, in some cases we could not find the household electrification rates and instead used the proportion of the population. Second, we focused on access to grid electricity. So when there were electrification rates provided by different access types, we favored the numbers connected to the main grid. However, sometimes sources did not make such clear distinctions and in these cases we relied on the number provided. We ensured to exclude households whose primary source of electricity is solar power; this makes sense since these households are likely not connected to the grid. Third, in cases where we had two of three (total/rural/urban) electrification data points for a given year, we used the population data from the World Bank Development Indicators for that year and calculated the third value. This calculation is superior to trend-based simulations since it takes the population levels into account.

We used many different sources to collect the electrification data. First, we used the national census where available. We thought this to be the most reliable source of electrification data. These data were generally obtained either from the country-specific national statistical offices or from hard-copy reports. Second, we used nationally representative household surveys that included questions on electricity access. As with the census, we sometimes used survey reports that were published by the national statistical office or downloaded the actual survey data and calculated the electrification rate using the appropriate variable. When neither the census nor national representative surveys were available, we used other reliable government agency statistics and published journal articles. We used data from the Demographic & Health Survey only when its rates were in line with the trend. In cases where multiple sources listed different electrification rates for a given year, we used the more credible and nationally representative source. The dataset is accompanied by a reference document that lists the source used for each separate observation.

2.1. Data coverage

In total, we have 1065 observations for 124 countries across 15 different regions in Asia, Africa, Latin America, Middle East, Eastern Europe and the Caribbean between years 1949–2015. The number of data points for total electrification rate is 1008; the numbers for rural and urban electrification are 723 and 666, respectively. All numbers used in the analysis are based on the data we have collected. Unlike World Bank (2017), we do not simulate any data points.

Table S1 shows data coverage by region. There is considerable variation in the data collected across different regions. Some countries (e.g. in Latin America) had representative surveys conducted every few years (or sometimes every year) allowing us to collect rich electrification data. Governments in some others (e.g. in the Middle East) put out reliable electrification data at less regular intervals. Eastern and Western Africa have the most number of countries in the dataset (16 each), whereas Eastern Europe and East Asia have the least number of countries (2 each). South America with 12 countries has the most comprehensive for total, urban, and rural electrification rates. Along with South America, both East and West Africa represent the regions with the most electrification data available. On the other hand, Southern and Eastern Europe have among the least available data, in part because the electrification rates in these countries reached 100% early on.

Fig. S1 shows variation in data coverage over time. It shows that the available data increased over time, a trend that is consistent with more nationally representative household surveys over time. It is also possible that national governments were more better at collecting electrification data for both rural and urban areas and more open at releasing them to the wider public over time. To compare the coverage of World Bank (2017) and the new database, see Fig. S14.

2.2. World Bank: global tracking framework data

The World Bank GTF for the United Nations Sustainable Energy For All (SE4ALL) initiative contains electrification data (total, rural, urban) based on nationally representative household surveys (World Bank, 2017). The data are based on about five hundred surveys, and missing values are then imputed with results from statistical simulations. The dataset contains observations for the years 1990–2012 for 198 countries. The total electrification rate is available for 24.7 years for the average country, though the vast majority of observations are simulated. The key difference between the GTF and our data is thus that we only use actual observations based on reliable, nationally representative data. Fig. S11 compares our data with the GTF data.

There are multiple differences between our data and the GTF. For instance, GTF used survey sources to document that Namibia had achieved 37% electrification in 2001. However, the census for the same year lists a 32% electrification rate. The discrepancies are more prevalent, however, when GTF uses simulations: Nigeria and Yemen are listed as having a 43% and 51% electrification rate in 2006 and 2004 respectively, whereas we find an electrification rate of 21% and 42% when we use a nationally representative survey and census information. The disparities are not limited to Africa or an overestimation of electrification rates. For example, the GTF lists Thailand as having an electrification rate of 82% in 1996 but we use census sources and find that the country had already achieved 96% electrification.

To ensure that the results below were not driven by ceiling effects, we removed countries from the regression analysis after they reached a 99% electrification rate. To see why leaving them in the dataset would be problematic, visualize a figure that has time on the x-axis, and electrification on the y-axis. A long series of values above 99% would gradually flatten the effect of time. Thus, we set observations to missing once they reach 99%, which in practice means that the country has achieved full electrification. We do so separately for total, urban, and rural electrification in both the GTF and our dataset. For an analysis of time effects without the removal of fully electrified countries, see Tables S6–S8.

Table 1
Dependent variable: electrification rate (0–100%). The World Bank sample is based on World Bank (2017) and limited to the countries in our sample to allow direct comparison. Once a country reached an electrification rate above 99%, additional observations are dropped from the analysis. This criterion is applied separately for total, rural, and urban electrification rate. Eastern European countries are not analyzed as a separate region, but are included in Model (1). Standard errors clustered by country. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	New Database						WB
	All	East/Southeast Asia	Latin America	Middle East/N Africa	South Asia	SSA	All
Panel A: Total Electrification							
Time	1.30***	2.18***	1.08***	1.45***	1.85***	0.99***	1.02***
	(0.08)	(0.40)	(0.08)	(0.19)	(0.07)	(0.13)	(0.09)
Country FE	✓	✓	✓	✓	✓	✓	✓
Observations	927	127	222	116	65	381	2478
R^2	0.69	0.75	0.84	0.68	0.89	0.56	0.58
# Countries	124	16	27	18	7	46	124
Panel B: Rural Electrification							
Time	1.51***	1.94***	1.57***	2.29***	2.11***	0.66***	0.98***
	(0.10)	(0.29)	(0.14)	(0.20)	(0.16)	(0.13)	(0.11)
Country FE	✓	✓	✓	✓	✓	✓	✓
Observations	643	85	158	62	37	289	2337
R^2	0.70	0.79	0.82	0.86	0.86	0.37	0.43
# Countries	111	15	25	13	6	46	110
Panel C: Urban Electrification							
Time	0.96***	1.27**	0.73***	0.95***	1.36***	1.22***	1.00***
	(0.07)	(0.51)	(0.10)	(0.17)	(0.15)	(0.11)	(0.13)
Country FE	✓	✓	✓	✓	✓	✓	✓
Observations	567	67	135	49	36	269	1857
R^2	0.56	0.48	0.73	0.43	0.86	0.57	0.34
# Countries	110	15	26	12	6	45	109

2.3. Other variables and statistical methods

The other variables used in the analysis are the following. *GDP per capita* is measured in USD (2010 constant prices), and logarithmized. *Population density* is measured in thousand people per square kilometer (k/sqkm). *Urban population share* is measured as percentage $(0-100)$ of people living in urban areas. *Natural resource rents* is measured as percentage $(0-100)$ of total GDP. Variables include coal, natural gas, oil, fossil fuel, and total natural resource rents. These variables were obtained from the World Development Indicators. *Hydro potential* is measured as a country's hydropower potential (in kWh) divided by its population (in thousands); the ratio is then logarithmized. The data come from Hoes et al. (2017). *Democracy* is an index ranging from -10 to 10, where higher values denote more democratic countries. The source for these data is the Polity IV dataset version 2015. Finally, *Time* is a time counter, starting at 1 in 1950. For summary statistics, see Table S2.

We used the following statistical methods. In Table 1, we estimated a linear model with least squares (OLS) and standard errors clustered by country. In Table S13, we verify that our results are robust when using a fractional response model that accounts for the bounded nature of electrification; the results remain about the same. In Fig. 3, we plot electrification rates against logarithmized GDP per capita. We then overlay a semi-parametric estimate of the relation between the two variables based on a generalized additive model (GAM). The effect of GDP per capita is allowed to be nonlinear by adding smoothing functions.

3. Global electrification trends

Our dataset contains three primary measures: total, rural, and urban electrification rates. Each rate is measured as a percentage $(0-100)$ of either households or respective populations.[2] The measures are mostly based on national censuses and statistically representative household surveys; in some cases, we also use official government statistics and secondary sources.

Fig. 1 illustrates global progress in overall electrification. Panel (a) shows the electrification rate around the year 1990 and Panel (b) around the year 2010. As the figure shows, electrification rates have steadily improved across all regions. While most regions are already approaching universal electrification, Sub-Saharan Africa continues to lag behind the rest of the world. For an illustration of patterns over time for each country, see Fig. S12.

In Fig. 2, we show the same patterns for rural electrification rates in particular (for urban electrification, see Fig. S2). Here comparisons are complicated by the paucity of data around the year 1990. For countries that do have data for both time periods, we see very rapid progress in Latin America and some progress in other regions. The maps also show that the explanation for low electrification rates in Sub-Saharan Africa lies with the combination of large rural populations with stubbornly low household electrification rates. The World Bank GTF data is shown on a map in Fig. S3–S5.

Next, we turn to quantifying progress in electrification over time. In Table 1, we use a linear regression to estimate progress in total, rural, and urban electrification over time. We regress rural electrification rate on country-specific intercepts (i.e., country fixed effects) and a linear time trend. The coefficients thus represent the average annual change in the percentage of electrified households/populations. Model 7 uses

[2] The use of populations does not alter the electrification rates significantly. For example, we checked the total, urban and rural electrification rates for the years 1987–2010 in India using the National Sample Survey weighting the data by household size. We found an average discrepancy of only 2.6%, 0.7% and 1.6% points for total, urban and rural electrification rates respectively.

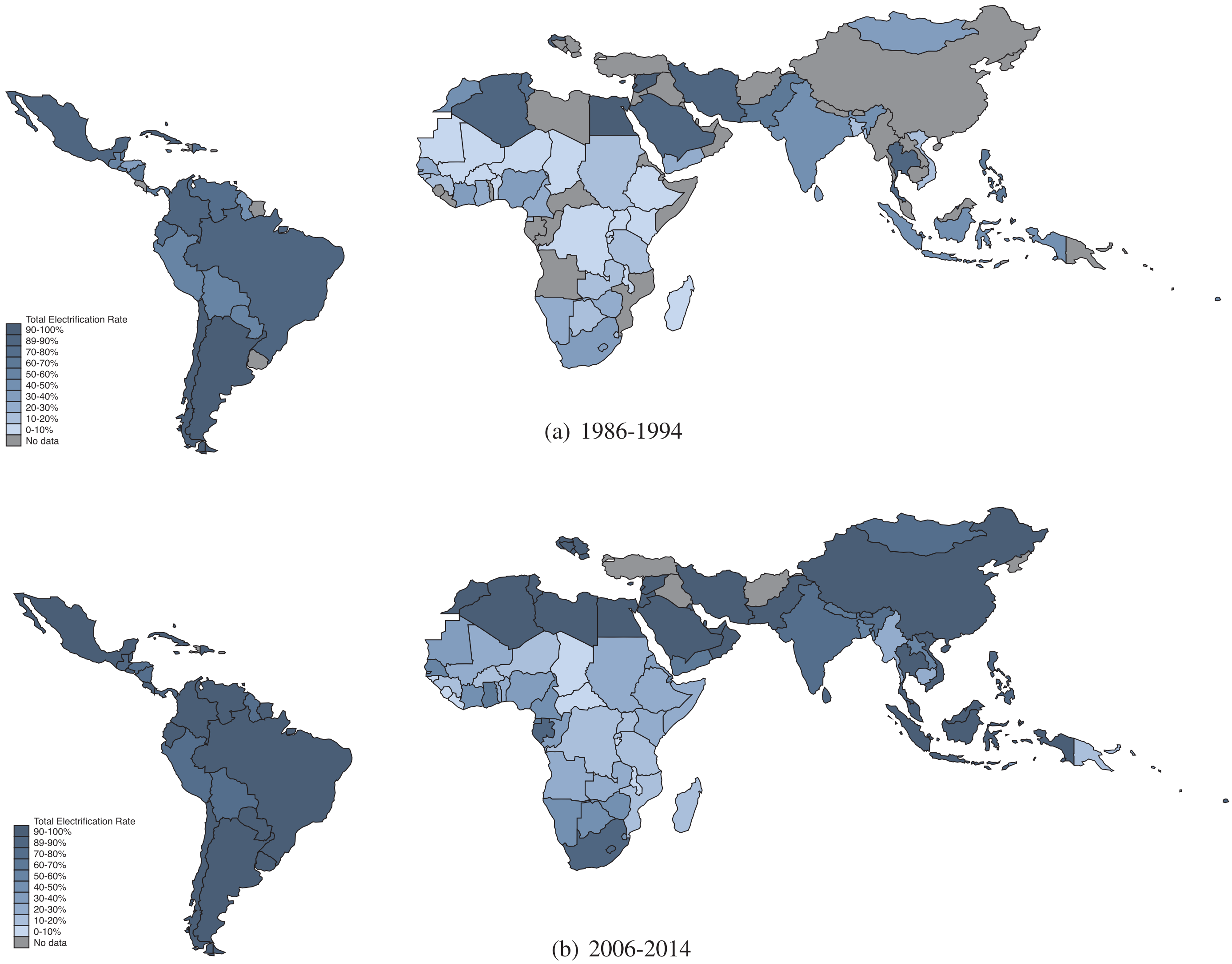

Fig. 1. Total electrification rates. Panel (a) shows the average electrification rates by country for all observations between years 1986 and 1994; panel (b) shows the same average for all observations between 2006 and 2014. Only countries in our sample (N = 124) are shown.

World Bank GTF data and Model 1 our own data. Models 2–6 use our own data but focus on different regions.

The table reveals a few patterns of importance. First, the World Bank data understates progress in total, rural, and urban electrification. For total electrification, the rate of improvement is almost 30% higher than that estimated by the World Bank (coefficients 1.30 and 1.02, respectively); for rural electrification, the difference is over 50% (coefficients 0.98 and 1.51, respectively). Only the estimated coefficient (0.96) for the urban electrification rate is approximately the same when comparing our data to the World Bank's simulations (1.00). When we do not use any simulated data, we see a much more positive pattern of progress in electrification than according to the World Bank's estimates. Indeed, if we only use observations from the World Bank data that are also in our dataset – and thus likely not based on simulations – the difference between our and the Bank's estimates decreases (Table S9). To ensure that unbalanced data are not affecting our main results, we also replicate them by taking collapsing the data into 5-year averages. The results are very similar (Table S10). Next, we computed the region-specific trends using the Word Bank data in Table S11; we find that using the World Bank leads systematically to lower yearly growth trends compared to the new data. The sole exception is South Asia, for which the World Bank data suggest more optimistic time trends. Lastly, we replicated our estimates using only post-1990 data (Table S12). We continue to find a higher growth rate in our data than in the World Bank's. Qualitatively, the main differences using post-1990 data are that the trend in East Asia declines whereas the trend in South Asia increases. Both results make sense: East Asia's electrification picked up substantively in the 1980s; South Asia, on the other hand, accelerated the pace of electrification later.

Second, the table confirms that Sub-Saharan Africa has made much less progress in electrification than other regions: even Latin America, which has historically had much higher electrification rates than most African countries, has outperformed Sub-Saharan Africa overall (coefficients 0.99 and 1.08 for total electrification, respectively). Finally, Sub-Saharan Africa is the only region in which urban electrification has made faster progress than rural electrification. Everywhere else in the world, progress in urban electrification has been slower, and the most straightforward explanation for the rural-urban difference is that outside Sub-Saharan Africa, urban electrification rates have been very high.

In Fig. S13, we simulate patterns of electrification using a quadratic time trend to allow for nonlinear trajectories. The conclusion remains mostly unchanged, with a few additional implications. In most regions, the growth of electrification rates has been approximately linear, and Sub-Saharan Africa remains the region with the slowest progress. The most interesting case is South Asia, which for a long time made very

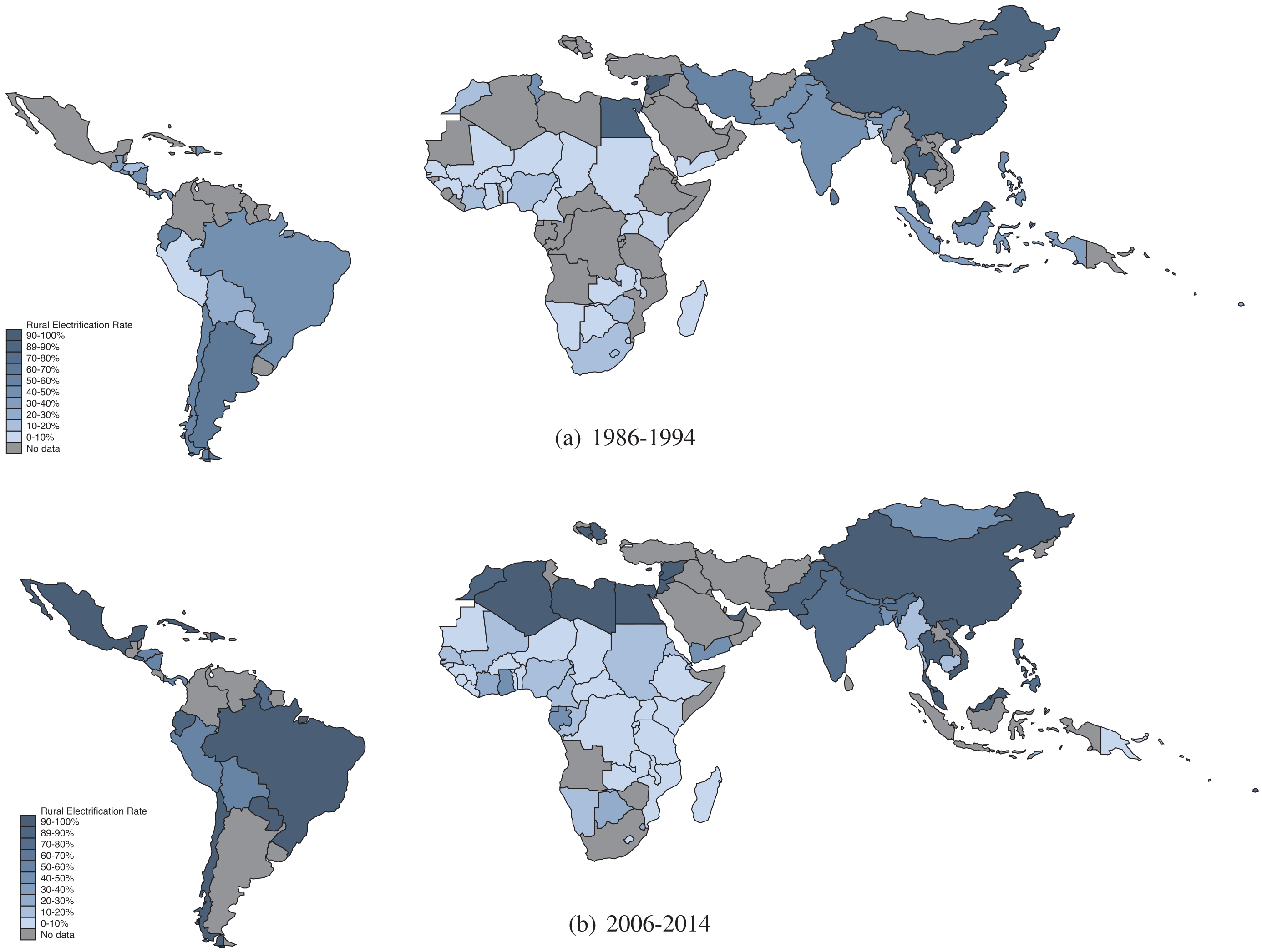

Fig. 2. Rural electrification rates. Panel (a) shows the average electrification rates by country for all observations between years 1986 and 1994; panel (b) shows the same average for all observations between 2006 and 2014. Only countries in our sample (N = 124) are shown.

little progress but has benefited from accelerated electrification for the past two decades.

4. Variation in pace of electrification

To describe patterns of variation in the pace of electrification, we begin with the conventional hypothesis that economic growth and electrification are strongly associated (Barnes, 2014; Greenstone, 2014). While electrification can itself contribute to economic growth (Dinkelman, 2011), the opposite causal mechanism is perhaps even more important: higher household incomes enable people to invest in household connections and pay for electricity (Foley, 1992).

To establish a baseline, Fig. 3 shows the association between logarithmized GDP per capita (USD, 2010 constant prices) and rural or total electrification rates. The x-axis shows GDP per capita and y-axis the electrification rate. To capture the possible nonlinear relationship, we fit a semi-parametric line based on a general additive model.

As the figure shows, the association between income levels and electrification rates is robust. For both rural and total electrification, electrification rates increase rapidly with wealth. Already at a per-capita income of USD 3000, total electrification rates reach 75% and rural electrification rates 50%. On the other hand, the graph also shows considerable variation around the predicted relationship based on the general additive model. Except for the very lowest and highest levels of GDP per capita, many countries underperform or overperform relative to the level predicted by GDP per capita alone. For similar graphs with variables other than per capita income, see Fig. S6–S9.

We next consider the covariates that predict deviations from the trend predicted by GDP per capita alone. In these models, the dependent variable is the deviation from the value predicted by logarithmized GDP per capita. The factors we consider capture plausible explanations for over- or underperformance, holding constant per capita income. Urbanization and population density reduce the cost of household electrification (Oparaku, 2003); natural resource rents provide funds for national electrification programs (Squalli, 2007); and democratic governments have, compare to their authoritarian counterparts, stronger incentives to provide electricity to households (Min, 2015). We examine the extent to which these factors can explain divergence from the degree of total, rural, and urban electrification across the world. The residuals are modeled as a linear function of these covariates, controlling for time. As before, the standard errors are clustered by country.

The results are shown in Table 2. The dependent variable is the observed (total, rural, or urban) electrification rate less the expected electrification rate based on logarithmized GDP per capita. The models vary only by the inclusion or exclusion of different explanatory variables. The last model includes all variables. Variance inflation factors, which can indicate multicollinearity issues, are below 3. Multicollinearity is therefore not a concern. For additional variables on natural resource rents, see Tables S3–S5. In Tables S14 and S15, we lag

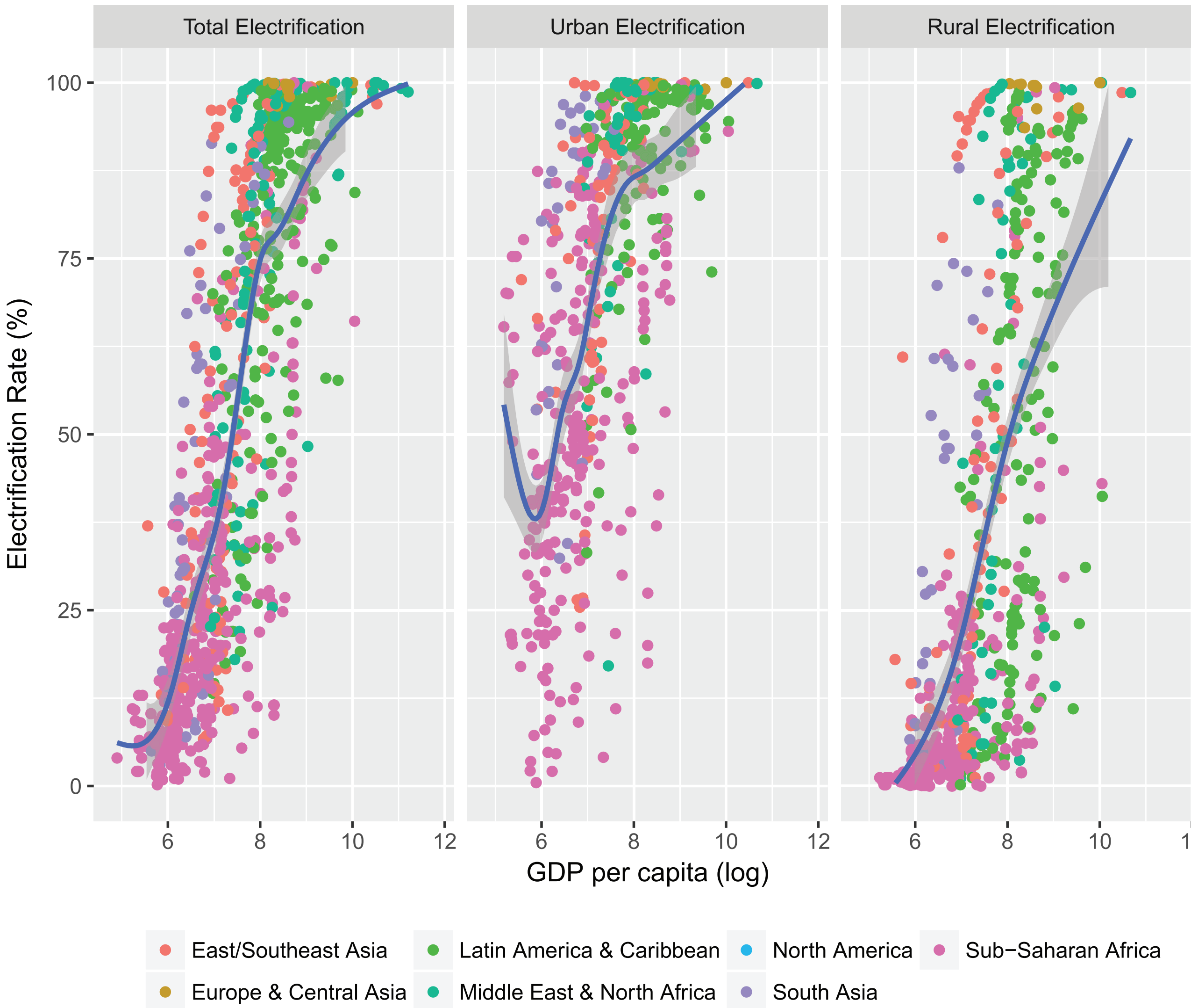

Fig. 3. Electrification rates and GDP per capita (logged). The line is a semi-parametric estimate based on a general additive model.

all independent variables by three, respectively five years, with no incidence on our estimates.

As the tables show, high population densities are a robust predictor of overperformance in both total and rural electrification, similar to findings reported by Steckel et al. (2017) based on a panel data analysis. The coefficients for population density range from 21.6 to 56.5, depending on dependent variable and model In contrast, the association between urban population share and rural electrification is relatively weak and subject to statistical uncertainty, with small coefficients that are statistically significant in only three out of six models. This result supports the hypothesis that a high urban population share mostly increases electrification rates mechanically, as urban areas are easier to electrify than rural areas because of the clustering of households. Another interesting result from the analysis is the negative correlation between fossil fuel rents and electrification: controlling for income effects, dependence on fossil fuels tends to reduce overall electrification rates, consistent with the resource curse hypothesis (Ross, 1999). Finally, controlling for per-capita income, we see little evidence for the positive benefits of democratic political institutions.

5. Conclusion and policy implications

Here we have described and analyzed a new database of national, rural, and urban electrification across the developing world. Using comprehensive and reliable data from nationally representative surveys in 124 countries outside the previously electrified OECD and post-communist world, where possible from the year 1960, we have shown that previous estimates of nation-level progress toward universal electrification over time have been overly pessimistic. We have also shown that the underestimation stem from interpolation of country-level electrification rates, whereas excluding or including the pre-1990 observations is not important. Our analysis demonstrates that total, rural, and urban electrification rates have increased rapidly across the world. GDP per capita remains a powerful covariate of high electrification rates, but urbanization and high population densities can explain why some relatively poor countries have improved their household electricity access rates at a rapid pace.

The first contribution of this research is a robust baseline for tracking progress in the universalization of energy access. A key feature of the SE4ALL initiative is that global, regional, and national targets are quantified and progress tracked over time. We contribute to this important global aspiration by providing a comprehensive, reliable, and freely available dataset of total, rural, and urban electrification rates. The dataset not only helps policymakers assess their own progress and identify historical episodes of unusually rapid electrification in other countries, but also offers the international community a rich repository of historical data on plausible rates of progress over time in different circumstances.

Table 2
Dependent variables: observed total/rural/urban electrification rates minus expected electrification rate based on logarithmized GDP per capita. Two outliers (Singapore and Timor-Leste) are removed from the sample (their inclusion does not affect the results; see Table S16). Standard errors clustered by country. *p < 0.10, **p < 0.05, ***p < 0.01.

Panel A: Total Electrification	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Time	0.63***	0.59***	0.61***	0.67***	0.72***	0.63***	0.64***
	(0.07)	(0.07)	(0.07)	(0.09)	(0.09)	(0.09)	(0.13)
Population Density (k/sqkm)	21.60***						26.63**
	(7.59)						(12.59)
Urban Pop. Share		0.17***					0.23***
		(0.06)					(0.07)
Hydro Potential per Capita (log) (kWh/k)			− 1.44				− 0.09
			(0.91)				(1.01)
Oil, Gas, Coal Rents (% of GDP)				− 0.26*			0.01
				(0.14)			(0.23)
Nat. Resource Rents (% of GDP)					− 0.43***		− 0.39**
					(0.11)		(0.18)
Democracy						0.10	− 0.30
						(0.28)	(0.31)
Constant	− 32.51***	− 35.66***	− 26.70***	− 31.21***	− 31.09***	− 30.83***	− 39.80***
	(3.46)	(3.47)	(4.39)	(4.42)	(4.47)	(4.11)	(7.19)
Observations	894	899	898	849	838	863	806
R^2	0.19	0.18	0.16	0.13	0.16	0.15	0.24
Panel B: Rural Electrification	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Time	0.71***	0.76***	0.71***	0.72***	0.81***	0.76***	0.76***
	(0.11)	(0.10)	(0.11)	(0.15)	(0.15)	(0.12)	(0.17)
Population Density (k/sqkm)	56.50***						52.30**
	(20.85)						(23.59)
Urban Pop. Share		0.06					0.15
		(0.11)					(0.11)
Hydro Potential per Capita (log) (kWh/k)			− 3.41**				− 1.25
			(1.47)				(1.69)
Oil, Gas, Coal Rents (% of GDP)				− 0.25			0.25
				(0.23)			(0.33)
Nat. Resource Rents (% of GDP)					− 0.50***		− 0.50*
					(0.18)		(0.28)
Democracy						0.04	− 0.35
						(0.45)	(0.46)
Constant	− 39.89***	− 39.86***	− 28.03***	− 34.19***	− 35.50***	− 37.65***	− 41.87***
	(5.39)	(7.38)	(7.17)	(7.91)	(7.84)	(5.61)	(10.02)
Observations	616	621	621	579	571	611	566
R^2	0.22	0.14	0.17	0.09	0.12	0.13	0.22
Panel C: Urban Electrification	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Time	0.29***	0.31***	0.31***	0.33***	0.42***	0.34***	0.45***
	(0.08)	(0.08)	(0.09)	(0.11)	(0.10)	(0.10)	(0.14)
Population Density (k/sqkm)	32.29***						40.22***
	(8.21)						(11.76)
Urban Pop. Share		0.12					0.16**
		(0.07)					(0.08)
Hydro Potential per Capita (log) (kWh/k)			− 0.58				1.30
			(1.16)				(1.21)
Oil, Gas, Coal Rents (% of GDP)				− 0.37**			− 0.04
				(0.18)			(0.34)
Nat. Resource Rents (% of GDP)					− 0.43***		− 0.39
					(0.16)		(0.29)
Democracy						− 0.03	− 0.57*
						(0.26)	(0.30)
Constant	− 16.25***	− 19.16***	− 13.17**	− 13.68**	− 15.91***	− 15.34***	− 29.69***
	(4.20)	(4.44)	(5.69)	(5.82)	(5.52)	(4.62)	(8.37)
Observations	562	567	567	526	518	557	513
R^2	0.09	0.06	0.04	0.05	0.08	0.04	0.16

A broader lesson for efforts to track global development goals pertains to data validation. We commend the GTF for establishing clear guidelines for monitoring progress and for developing measurement instruments in pilot surveys across the world, but we caution against efforts to create historical datasets based on imputation, simulations, or data sources that are not carefully validated. As we have shown, careful validation of national-level data on key development outcomes can avoid pitfalls, such as underestimating historical progress in the case of changing electrification rates over time.

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Appendix A. Supplementary data

Data and additional material is available on Harvard Davaterse https://doi.org/10.7910/DVN/BZBKJP. Supplementary data associated with this article can also be found in the online version at doi:10.1016/j.enpol.2018.07.018.

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