IS THE ELECTRICITY SECTOR A WEAK LINK IN DEVELOPMENT?

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Working Paper 32041
http://www.nber.org/papers/w32041

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
January 2024, Revised April 2026

For helpful comments, we thank David Argente, Andy Atkeson, David Baqaee, Susanto Basu, Saki Bigio, Paco Buera, Joe Kaboski, Stuti Khemani, Fernando Leibovici, Sam Kortum, Elisa Rubbo, Todd Schoellman, Yongs Shin, Robert Ulbricht, Rosen Valchev, and Jon Vogel, plus seminar participants at Boston College, Columbia, CUHK Shenzhen, Harvard, MIT, Peking University HSBC Business School, Peking University Institute for New Structural Economics, Virginia Commonwealth, Washington University in St. Louis, UCLA, UNH, the World Bank, and participants at various conferences. For outstanding research assistance, we thank Will DeCesare, Isaac Otoo, Savannah Quick, Jose Ramos, Samir Rein, and Natasha Swindle. We thank Stephie Fried and Christos Makridis for their input on an earlier version of this project. This project was supported by the IGC. All potential errors are our own. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 32041
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JEL No. E23, O11, O41

ABSTRACT

This paper evaluates the case that the electricity sector is a weak link in the development of low-income countries. To do so, we build a database of electricity inputs and outputs for 100 countries of all income levels and use it to measure electricity-sector total-factor productivity (TFP). We document that electricity TFP varies considerably less across low- and high-income countries than aggregate TFP. We then use the data to parameterize a multi-sector growth model in which electricity is a strong complement to other inputs in production and the electricity sector faces distortions in its own input and output markets. Quantitatively, the model predicts only modest long-run GDP gains from raising electricity TFP or removing distortions. These predictions are inconsistent with the view that electricity is a weak link. We show that parameterizations making electricity a weak link would require the sector to be counterfactually large or unproductive.

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1. Introduction

This paper evaluates the case that the electricity sector is a 'weak link' holding back the development of low-income economies. On its face, the case is a strong one. Electricity is an essential input for nearly all goods and services that characterize modern economies, and a common policy view is that the electricity sector is a bottleneck that is constraining other sectors in developing countries today. For example, World Bank president Ajay Banga describes electricity as "the bedrock for jobs, opportunity, and economic growth," and Sidi Ould Tah, head of the African Development Bank, writes that "reliable, affordable power is the fastest multiplier for small and medium enterprises." Development institutions are putting significant resources behind this conviction as well: the World Bank committed 64 billion dollars to electricity investments from 2000 to 2014, for example, and has plans to double their current electricity spending by 2030.[1]

Will significant upgrades to electricity infrastructure help unleash long-run economic growth in low-income economies? To what extent is the electricity sector currently holding back the growth of other sectors, and, as a result, the aggregate economy? This paper takes up these questions from a macroeconomic perspective, building on the growing literature focused on whether certain sectors play pivotal roles in explaining international differences in output per worker (such as agriculture (Restuccia, Yang and Zhu, 2008; Caunedo and Keller, 2020; Boppart, Kiernan, Malmberg and Krusell, 2023), or the investment-goods sector (Hsieh and Klenow, 2007; Herrendorf and Valentinyi, 2012)). The idea that electricity – or energy more broadly – has few good substitutes in production has featured prominently in long-run macroeconomic analyses of energy inputs (Atkeson and Kehoe, 1999; Hassler, Krusell and Olovsson, 2021; Casey, 2023). Yet, due to data limitations, no prior study has focused on whether the electricity sector plays an outsized role in explaining cross-country productivity differences and the growth of less-developed countries.

Our study begins by creating a new database of real inputs, outputs, and cost shares in the electricity sectors of 100 countries of all income levels. These data allow us to measure TFP in the electricity production and generation sectors of each country. A key advantage of the database is that electricity output is measured directly in physical quantities—kilowatt hours—which facilitates cross-country comparisons. Capital inputs, representing power plants and power lines, and primary energy inputs, such as oil or natural gas, are similarly measured in physical units. We show that the electricity-sector production function is well described by a nested Cobb-Douglas function of labor and a composite input which combines capital and primary energy inputs (e.g. fuel). We can then compute electricity-sector TFP in each country as a Solow residual.

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[1] See World Bank Independent Evaluation Group (2015), African Development Bank Group (2016), and World Bank Group (2025) for example.

We document that electricity TFP measures show surprisingly little variation across less- and more-developed economies. The poorest countries in our database have their electricity TFP around 75 percent of the U.S. level. By comparison, aggregate TFP is around 20 percent of the U.S. level for these same countries. We show that the weak relationship between electricity TFP and GDP per capita is not driven by the mix of electricity generation: results are similar when excluding major hydropower or nuclear electricity producers. Nor is it driven by differences in country size, the age of the electricity capital stock, or assumptions about the extent of returns to scale in the electricity sector. The strongest empirical predictor of low electricity TFP is high transmission and distribution losses, which are significantly more pervasive in low-income economies.

Our cross-country evidence does not provide much support for the assertion that electricity is a particularly unproductive sector in developing countries. Yet there could still be significant aggregate gains from raising electricity TFP to the world frontier, given that electricity is a sector with few good substitutes. Moreover, the binding constraint may not be low electricity TFP per se, but rather a shortage of electricity capital or distortions that impair electricity markets. Many developing countries have unreliable power supplies that require firms to self-generate power at considerably higher costs (see e.g. Eberhard, Rosnes, Shkaratan and Vennemo, 2011; Foster and Steinbuks, 2008). Price controls can depress investment in new generation capacity (McRae, 2015; Burgess, Greenstone, Ryan and Sudarshan, 2020; Trimble, Kojima, Arroyo and Mohammadzadeh, 2016). Removing these distortions could also boost aggregate GDP significantly.

To address these possibilities, we build a multi-sector neoclassical growth model to simulate the aggregate effects of improving the electricity sector in developing economies. The model features electricity as a strong complement to other inputs, reflecting the idea that such complementarities can give rise to weak links (Hirschman, 1958; Kremer, 1993; Jones, 2011). We capture this using an aggregate CES production function with a low elasticity of substitution between electricity and a non-electricity composite input, as in Atkeson and Kehoe (1999); Hassler et al. (2021); Casey (2023). Electricity production itself uses a nested Cobb-Douglas function of labor and a capital-fuel composite, mirroring our empirical specification. The non-electricity composite is a standard Cobb-Douglas aggregate of capital and labor, as in the canonical growth model, with its own sector-specific TFP term. This allows us to vary productivity in the electricity and non-electricity sectors independently. To parsimoniously capture distortions in the electricity sector, we introduce tax-like wedges in both input and output markets, following e.g. Baqaee and Farhi (2020).

We parameterize the model country-by-country to match our electricity TFP estimates as well as levels of income per capita and other evidence that disciplines the size of distortions in the electricity sector. Despite its simplicity, the model does well in matching salient untargeted features of the cross-country data. In particular, aggregate and sector-specific capital-labor ratios correspond closely to their empirical counterparts, as do labor and capital productivities in electricity. We then examine whether raising electricity TFP to the world frontier would deliver long-run GDP per capita gains that are large in absolute terms or disproportionate relative to the electricity sector's size. We employ two benchmarks for comparison. The first is Hulten (1978)'s formula, which multiplies the Domar weight of electricity by the change in electricity TFP. The second is the formula of Baqaee and Malmberg (2025), which extends the Hulten approach by incorporating long-run responses in capital accumulation. We similarly examine the gains from removing electricity-sector distortions in each country.

Our quantitative exercises predict that the long-run GDP gains from raising electricity TFP to the world frontier are modest in nearly all economies, with an average gain of around 1.7 percent for countries in the bottom half of the world income distribution. Just five countries – Ethiopia, Kenya, Haiti, Jamaica, and Nicaragua – would see gains of 4 percent or more. This pessimistic finding does not stem from the electricity TFP increases themselves being small: the average country sees a 45 percent increase in electricity TFP. Instead, the parameterized model points to electricity being even less important than suggested by its small size. By Hulten's formula, countries in the lower half of the income distribution should gain an average of 1.9 percent. Only Ethiopia and Kenya decisively clear the Hulten hurdle, with long-run GDP gains around 4 times his benchmark. The comparisons are similarly unfavorable when using the Baqaee and Malmberg (2025) benchmark and when comparing growth of consumption rather than output. The implication is that electricity is not generally a weak-link sector in the developing world, at least not when the solution works through raising electiricity TFP to the world frontier.

What about removing distortions in the electricity output markets? The parameterized model predicts larger long-run GDP gains than those from raising TFP to the frontier. But the average magnitude is again modest. Ethiopia and Kenya once again gain the most, as their calibrated distortions are the largest. Six other countries with substantial distortions see GDP gains of around 5 percent: Zambia, Mongolia, Ghana, Albania, Haiti, and Nicaragua. These gains should not be discounted. But they are also not what one would describe as a bedrock for growth. Nor are they typical in the developing world: the 41 other developing countries in our quantitative analysis gain just 0.9 percent in the long-run from removing electricity distortions. We find that removing investment distortions is even less effective at raising output and consumption, particularly when the output distortions are left in place.

So why does the electricity sector not behave like a weak link? To answer this question, we conduct several additional exercises using the calibrated model. First, we simulate the short-run effects of a counterfactual *decline* in electricity-sector TFP. This exercise parallels most macroeconomic studies of energy use, which focus on negative energy shocks such as wars or global supply disruptions. As in these studies, we find strong negative effects on GDP – that easily beat the Hulten benchmark – highlighting the asymmetric effects of TFP movements in sectors exhibiting strong complementaries (Baqaee and Farhi, 2019).

Next, we simulate the long-run effects of raising electricity TFP starting from a counterfactual world in which every country begins with an extremely low level of electricity TFP (just 5 percent of the level estimated from data). In this scenario, a 45 percent boost in electricity TFP would nearly double GDP per capita in the average developing country. Unfortunately, this counterfactual not only features electricity TFP levels that are far too low, but also electricity Domar weights that are an order of magnitude too high. The lesson is that conclusions about whether electricity is a weak link are not hard-wired into the model, but rather depend crucially on properties of the data.

Finally, we simulate the impacts of raising non-electricity TFP in our main calibrated model. For comparability, we raise every country's non-electricity TFP by the same factor as in the electricity TFP experiments – an average of 45 percent. The result is that countries in the bottom half of the world income distribution would more than double their GDP levels on average, roughly twice what Hulten predicts. To be sure, this is not a "policy experiment." If policymakers could pull the "raise TFP by forty-five percent" dial, they would have done so long ago. The point is that development multipliers are less likely to stem from fixing electricity than from shoring up productivity in the economy writ large. From a policy perspective, this suggests doubling down on bread-and-butter development objectives such as improving management practices, building worker skills in school and on the job, and promoting diffusion of the latest technologies.

Our study contributes to a growing literature on the role of electricity in development. One important topic we sidestep is the effects of extending electricity access to rural communities. We abstract from this issue since prominent recent empirical work points to very modest effects of increasing access. Lee, Miguel and Wolfram (2020) document negligible experimental demand for last-mile electricity connections in Kenya and limited economic impacts on those being connected at little or no cost to them.[2] Similarly, Burlig and Preonas (2024) estimate very modest economic effects of rural electricity access in India, including a precise null impact on consumption after five years. In the macro development space, our work has a more parsimonious model of distortions in electricity than Fried and Lagakos (2023), who study the effects of power outages in five Sub-Saharan African nations, but similar conclusions about the negative effects of distortions in countries with widespread outages and production using generators.[3]

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[2] Dabalen, Khemani, Lang and Timilsina (2026) conclude from this and other studies that "current market or economic conditions in small villages in rural Africa do not seem to be sufficient for economic activity to take off after electrification."

[3] Our study ignores complementarity between electricity provision and other types of infrastructure, such as roads. Using rich micro data on the electricity grid expansion and road building from Ethiopia, Moneke (2024) finds evidence

Our paper also adds to a recent strand of the macroeconomic literature that studies whether specific sectors play an outsized role in development (following, e.g., Hsieh and Klenow, 2007; Herrendorf and Valentinyi, 2012). Our paper's quantitative exercises are similar in spirit to those of Boppart, Kiernan, Malmberg and Krusell (2023), who argue that agriculture's TFP level is not as far behind the frontier, relative to others, as previous studies had claimed. Our setup is less general than those of Baqaee and Farhi (2019) and Dávila and Schaab (2023), though our model and results are for a dynamic setting, and capital accumulation plays an important role in our conclusions, unlike in theirs. Using growth models that more are general, but less tailored to electricity than ours, McNerney, Savoie, Caravelli, Carvalho and Farmer (2021) and Casal and Caunedo (2025) argue that cross-country differences in the input-output network help shape aggregate income differences, highlighting the importance of sectoral linkages for development. Alvarez, Argente, Lippi, Méndez and Van Patten (2023) and Buera, Hopenhayn, Trachter and Shin (2025) study economies with strategic complementarities and coordination failures that depress development, though neither focuses on electricity.

2. Measuring TFP of the Electricity Sector

In this section we calculate the TFP of the electricity sector in as many countries as the data allow. We first describe our data, and then document a series of empirical patterns of the sector to infer an aggregate production function for electricity. Next, we compute the electricity sector's TFP with the data and the inferred production function.

2.1. Data Sources

We compile data from various public and proprietary sources to construct a new cross-country data set on the electricity sector for the mid-2010s.

Electricity Capital Stocks Data on electricity capital were collected from the World Electric Power Plants (WEPP) database, provided by S&P Global Platts. The database provides a global inventory of more than 200,000 power plants. We use data for the year 2012 in our analysis and calculate aggregate capacity measured in MW. In our data, we calculate that the average country has 32,677 MW of capacity and 895 plants.[4] In the bottom quartile of the global income distribution, the average is 1,933 MW of capacity and 141 plants. In the top quartile, the average is 70,709

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of such complementarities, but still predicts quite modest aggregate impacts of electricity expansions overall.

[4] In the United States, the average home consumes around 10.8MWh of electricity per year. 32,677 MW of capacity would generate 286,250,520 MWh of electricity per year if operating continuously (8,760 hours), enough to power around 26.5 million U.S. homes. In 2012, there were approximately 121 million households.

MW from 2,372 plants. The average plant is 2.3 times larger in the top quartile than in the bottom quartile (29.39 MW vs. 12.82 MW).

Although WEPP data are comprehensive, they are unlikely to provide a complete accounting of all electricity-generating capital. In particular, the WEPP data do not provide information on electricity generators, which may be especially important in lower-income settings where grid electricity is less reliable. We supplement the information from WEPP with data we constructed on the capacity of imported electricity generators, inspired by Caselli and Wilson (2004). How successful we are in capturing the capital stock of generators depends on the extent to which countries domestically produce generators. For the United States, domestic production is likely non-trivial but only accounts for a trivial share of overall capacity. For most developing countries, we did not find much evidence of domestic production, and generators likely make up a more meaningful share of total electricity capacity.

We first collect data on the quantity of AC generator imports for 147 countries from the UN Comtrade database – the largest repository of international trade data, containing over 3 billion records. The data subdivide AC generators by electrical capacity: less than 75kVa, 75-375kVa, 375-750kVa, and more than 750 kVa. To be consistent with our other capacity data we convert these data into kW of capacity using a standard conversion factor of 0.8. Because each category of generators is a range, we calculate the quantity of generators by the minimum, mean, and maximum kW values of each category. In our baseline analysis, we are conservative and use the lower capacity range. We calculate that, on average, generator capacity accounts for 7.6 percent of overall capacity. In the bottom quartile of the income distribution, generator capacity accounts for 6.7 percent of overall capacity on average. In the top quartile, generator capacity accounts for 5.2 percent. If we use the higher capacity range, generator capacity accounts for 21 percent of overall capacity in the bottom quartile of the income distribution and 15 percent of overall capacity in the top quartile.

In addition to generation capital, we also measure transmission and distribution capital. Data on the capacity of transmission transformers, distribution transformers, and generator step-up transformers were provided by Kalt, Thunshirn and Haberl (2021). In practice, we do not make use of the transmission and distribution capital due to their high correlation with the generation capital. Conceptually, we impose that the production of electricity entails a Leontief relationship between generation capacity and transmission capital, i.e.,

$$K_E = \min[K_E^G, \psi K_E^{T\&D}]$$

The Leontief relationship captures the idea that the amount of electricity generated is constrained by the extent to which it can be distributed. In Figure A1, we show that the generating capacity and transmission and distribution capacity are nearly perfectly correlated, providing empirical support for our modeling decision.

Electricity Output and Inputs Data on physical electricity production and primary energy input were collected from the International Energy Agency (IEA).[5] We collected data on electricity and combined heat and power plants from the energy balance tables of each country for 2012. This allows us to construct total energy inputs and output in TJ. We convert the total output into MWh, using the conversion factor 1 TJ = 277.778 MWh. For total primary inputs (i.e. fuel), we convert to Million British Thermal Unit (MMBtu) using the conversion factor 1 TJ = 947.81798.

In addition to the electricity output and inputs from power plants, we estimate the output and inputs related to self-produced electricity from generators. To do this, we calculate electricity output and fuel inputs per MW of power plant capacity for each country, then scale these by self-generation capacity.

Finally, we adjust the amount of electricity produced to account for transmission and distribution (T&D) losses. T&D losses are efficiency losses *conditional on electricity being generated*: they capture energy that leaves a plant but never reaches end users because it is dissipated as heat in wires and transformers or stolen. Data on T&D losses are provided by the IEA. On average, these losses account for 14 percent of total output; they are 22 percent of total output in the bottom quartile of the world income distribution, and 7 percent in the top quartile.[6]

We calculate total electricity output in MWh as the sum of utility-generated and self-generated electricity:

$$E^{MWh} = E^{MWh}_{power\ plants}(1 - \text{share lost}) + E^{MWh}_{self\text{-}generation}.$$

The average across our countries is 4.96 MWh per capita. For the bottom quartile of the world income distribution, total electricity output per capita is 0.47 MWh, enough to power two 100-watt light bulbs for 6 hours a day for a full year. For the top quartile, total electricity output per capita is 11.8 MWh, around 25 times higher than the bottom one.

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[5] https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?

[6] These losses differ from blackouts or brownouts. A blackout is a failure to generate in the first place, so it shows up as lower generation relative to installed capacity, not as higher T&D losses. Because grid operators must balance supply and demand in real time to maintain frequency, any outage that cuts available generation after it has left a plant, for example a downed power line or transformer failure, will lead to scaled back generation and be reflected in lower measured output. Total utilization gaps may also reflect maintenance, input shortages, or a demand shortfall.

Electricity Employment Data on employment in the electricity sector were compiled from the national statistics offices of 131 countries. Most observations were collected from statistical yearbooks or industry censuses, with an average source year of 2012. In ancillary analysis, we estimate that there is not a strong relationship between the electricity share of utilities employment and GDP per capita. Accordingly, we scale each country's utilities employment by the predicted electricity share. We maximize our analysis sample in the most consistent way by using the set of scaled utilities employment and electricity employment (for countries where we only observe electricity-sector employment). Our findings are qualitatively and quantitatively robust to restricting our sample to countries that explicitly report electricity employment, but this results in a much smaller sample size. To be consistent with the other inputs, we also scale employment to account for the labor required for self-generation. We calculate the number of workers per MW of power plant capacity in each country and scale this by self-generation capacity.

Analysis Sample After combining all data sources, we have a total of 100 countries in our analysis sample. If we restrict attention to countries for which we can adjust for self-generation, we have data on 89 countries.

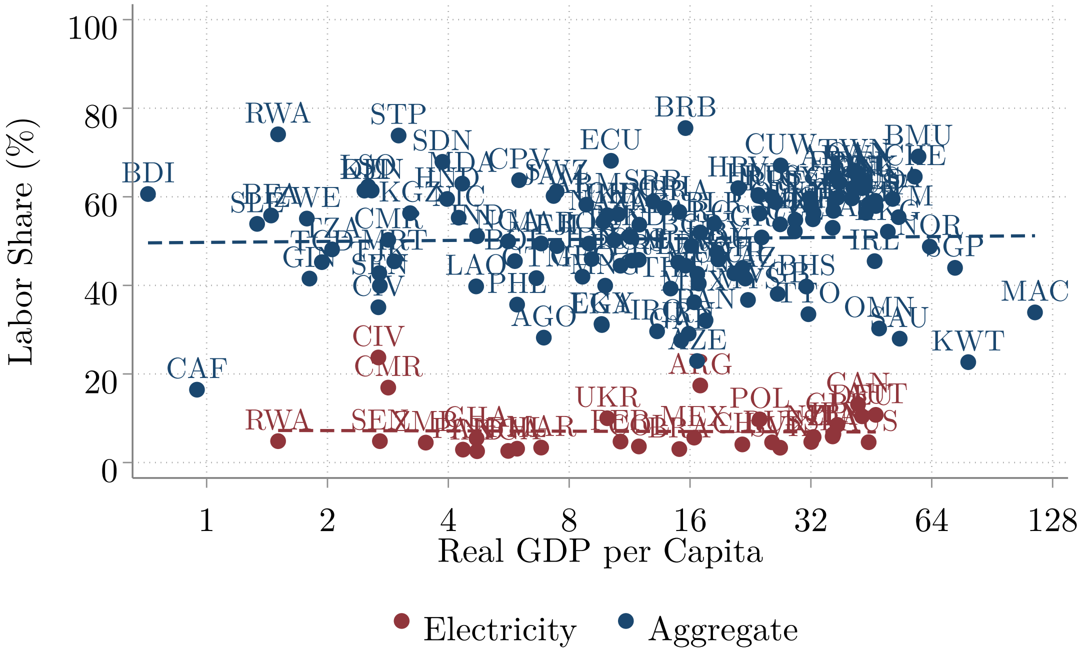
Labor Share We also sought to characterize labor's share in electricity production. To this end, we collected and harmonized data on privately owned electricity generation firms, extracting information from annual reports, financial statements, and SEC filings. This resulted in usable information for 69 electricity companies in 31 countries. For each company, we compute total payments to labor, total sales, and total purchases of intermediates (primary fuel inputs). We compute labor's share of revenue as total payments to labor divided by total electricity sales. To calculate the labor share of the entire sector, we aggregate across firm-years within each country.

Figure 1 plots labor's share of revenue in electricity (red dots) against aggregate labor shares from the PWT (blue dots) for the countries in our data. The average labor share in electricity is about 7 percent with little variation throughout the income distribution. A simple regression of labor's share in electricity on real GDP per capita yields a slope coefficient that is very small and statistically insignificant – a 10 percent increase in real GDP per capita is associated with a 0.009 percentage point decrease in the labor share, all else constant.

2.2. Electricity-Sector TFP

We would like to measure TFP in the electricity sector as a whole, and this requires taking a stand on the form of the production function. Specifically, we need a functional form $G(\cdot)$ where $E = A_E G(K_E, L_E, F)$, where F represents fuel inputs.

Figure 1: Labor's Share of Revenue in the Electricity Sector



Notes: This figure documents variation in the cross-country distribution of aggregate labor share and electricity sector labor share and how these shares change with real GDP per Capita. Data on real GDP per capital and the aggregate labor share for the year 2012 is taken from the Penn World Tables version 9.1. Data on the electricity sector labor share was collected and harmonized from the annual reports, financial statements, and SEC filings of 69 privately-owned electricity companies in 31 countries.

We first assume that $G(\cdot)$ exhibits constant returns to scale based on the standard replication argument. Suppose that some workers and machines have a technique to make one unit of electricity per year in one location. Then different workers and machines, in the same quantities, should be able to produce a second unit of electricity per year in a different location. Notice that this is *not* the same as assuming that a particular electricity plant can scale up infinitely without raising its costs. On the contrary, growth in the electricity sector may well be largely about expanding the number of electricity plants along the extensive margin.[7]

The fairly constant labor share of value added in the electricity sector suggests a Cobb-Douglas relationship between labor and other inputs. For capital and fuel, we follow tradition in this literature, which has long found very low substitutability between them (e.g., Dhrymes and Kurz,

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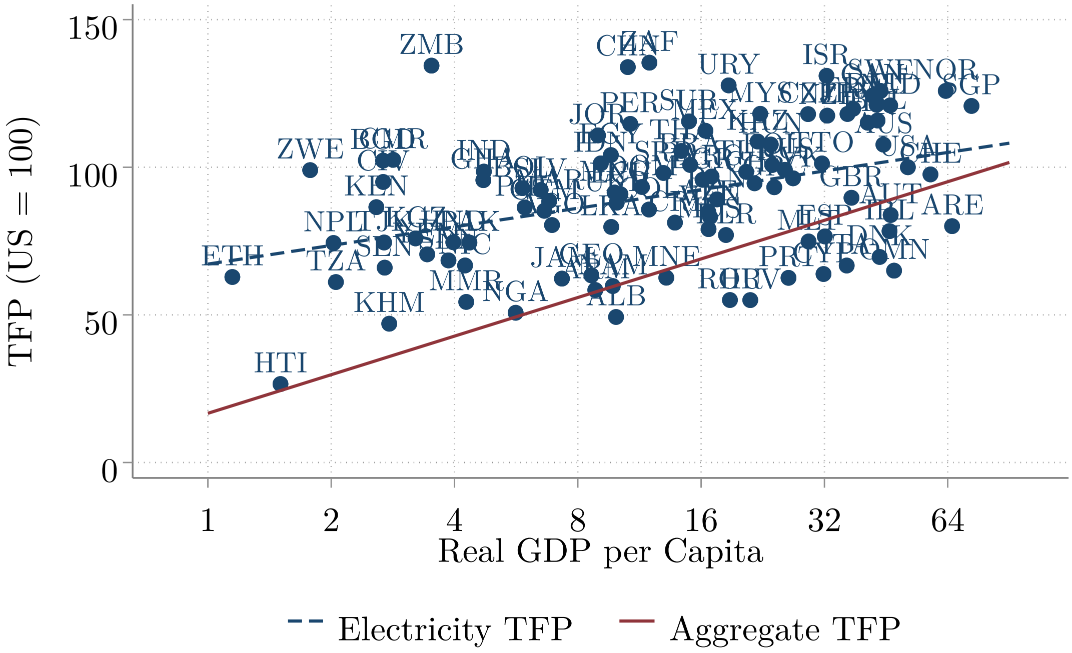
[7] One concern is that while fossil-fuel burning electricity plants may be subject to a replication argument, sites for hydro dams are few and far between, and cannot be scaled up easily. We will address this concern in several ways below, by controlling for the fraction of electricity that is produced by renewables, and by allowing for aggregate decreasing returns to scale in the electricity sector. Simply excluding countries with high shares of hydro (or nuclear) generation leaves our conclusions essentially unchanged.

Figure 2: Electricity-Sector TFP Across Countries (USA = 100)



Notes: This figure documents the relationship between measured TFP (electricity sector and aggregate) and real GDP per capita in thousand 2011 U.S. dollars. Data on real GDP per capita and aggregate measured TFP are taken from the Penn World Tables version 9.1. Data on measured TFP for the electricity sector is calculated from the data described in Section 2.1 and equation 1.

1964). Putting these assumptions together yields our aggregate production function for electricity:

$$E = A_E \left(\min\left[K_E, \chi F_E\right]\right)^{\theta_E} L_E^{1-\theta_E} \tag{1}$$

where χ represents the weight of fuel in the production function and θ_E denotes the importance of the capital-fuel bundle in electricity production. We allow χ to vary across countries because some countries use renewable electricity more intensively than others. Intuitively, a country that relies more on renewable energy requires less fuel to generate electricity, which leads to a higher capital-fuel ratio for its electricity sector, corresponding to a higher value of χ.

Using equation (1), we can measure TFP in the electricity sector in each country. As we take the electricity sector as competitive, the exponent over labor is equal to the share of labor expenditure over total revenue. We read from our micro-level data that this share averages 7 percent, which corresponds to a value of 0.93 for θ_E.

Figure 2 plots electricity TFP against GDP per capita, with the U.S. level normalized to 100. There is a small positive slope, which is statistically significant, but overall, we observe very little

Table 1: Alternate Regressions and Measures of Electricity TFP

	Electricity TFP (US = 100)				
	(1)	(2)	(3)	(4)	(5)
$\log_2$ GDP per capita	6.30***	7.30***	1.83	2.89**	5.77***
	(1.51)	(1.13)	(2.63)	(1.40)	(1.53)
Electricity Sector Returns to Scale	$\nu = 1.0$	$\nu = 0.9$	$\nu = 1.1$	$\nu = 1.0$	$\nu = 1.0$
Includes Small-scale Capital	No	No	No	No	Yes
Adjusted for Transmission Losses	Yes	Yes	Yes	No	Yes
Observations	100	100	100	100	89

Note: This table reports how electricity sector TFP varies with GDP per capita under alternative measures of electricity TFP. The first column reproduces the coefficient reported in the main body of the paper from a bivariate regression of electricity-sector TFP on GDP per capita in log base 2. The second and third columns recompute TFP assuming that the electricity sector exhibits decreasing returns to scale ($\nu = 0.9$) or increasing returns to scale ($\nu = 1.1$). Column 4 removes the adjustment we made to output to account for transmission losses. Column 5 include adjustments we made to include small-scale electricity capital, e.g., generators. Significance levels are indicated as * 0.10 ** 0.05 *** 0.01.

variation in electricity TFP compared to the aggregate TFP from the Penn World Tables. The poorest countries have around 75 percent of the TFP level in electricity as the richest ones, putting them close to the world productivity frontier. The electricity sector is thus a far cry from the investment-good and agriculture sectors, for example, for which there is at least as much variation as aggregate TFP, and possibly more (Hsieh and Klenow, 2007; Restuccia et al., 2008; Herrendorf, Rogerson and Valentinyi, 2022).

Our TFP results are robust to various controls and alternative measurement assumptions (Table 1). Alternative assumptions about aggregate returns to scale in the electricity sector do not change our conclusion that electricity TFP is similar in rich and poor countries. With aggregate decreasing returns to scale (of degree 0.9), the slope coefficient of electricity TFP on GDP per capita is only slightly larger than in Figure 2. With aggregate increasing returns to scale (of degree 1.1), the slope coefficient becomes even smaller and statistically insignificant from zero. When we exclude transmission and distribution losses the slope coefficient of electricity TFP is much smaller than in the main analysis. Finally, when we include our adjustments for self-production of electricity (through generators) the slope coefficient becomes slightly smaller than our baseline estimate.

We next report correlates of electricity TFP in our cross-section of countries (Table 2). We focus on variables that proxy for energy losses after production (T&D losses), the mix of generation types (hydro share), the age of the capital stock, the cost of connecting users (terrain ruggedness), and country size. We emphasize that these should not be interpreted as causal relationships. The goal is rather to understand which observables correlate most strongly with our electricity TFP measures.

Transmission and distribution losses stand out as the strongest predictor of electricity sector TFP: higher losses line up with lower electricity TFP and, once included, absorb the association with GDP per capita. The relationship between T&D losses and TFP remains stable as we include additional predictors. The ruggedness of the country is also a negative predictor of TFP. Higher ruggedness may reflect higher building costs for transmission and distribution, greater maintenance costs and downtime when repairs are needed, or reductions in optimal scale or density. We estimate that electricity TFP is increasing in the size of the country. The estimated coefficient on ruggedness is a third smaller and statistically insignificant when we include this variable, indicating that at least part of the variation may be captured by scale. The statistical inference of our analysis is not sensitive to the inclusion of region fixed effects. The takeaway of this analysis is these electricity TFP measures correlate closely (and negatively) with an intuitive measure of malaise in electricity generation distribution, namely the percent of output that is generated but then lost before it can reach final consumers.

Table 2: Correlates of Electricity TFP

	Electricity TFP (US = 100)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\log_2$ GDP per capita	6.30***	-0.43	-0.37	0.04	-0.27	0.38	0.90
	(1.51)	(1.78)	(1.77)	(1.78)	(1.80)	(1.79)	(2.36)
T&D Losses (%)		-1.64***	-1.54***	-1.54***	-1.54***	-1.49***	-1.52***
		(0.28)	(0.31)	(0.30)	(0.30)	(0.30)	(0.31)
Ruggedness (%)			-0.20*	-0.25**	-0.26**	-0.18	-0.22
			(0.10)	(0.12)	(0.12)	(0.12)	(0.14)
Hydro Share (%)				0.09	0.05	0.01	0.01
				(0.09)	(0.09)	(0.09)	(0.11)
Capital Age					0.26	0.21	0.35
					(0.26)	(0.24)	(0.27)
Log Area						2.54***	2.14**
						(0.93)	(1.03)
Observations	100	100	100	100	100	100	100
Region Fixed Effects	No	No	No	No	No	No	Yes
Adjusted R^2	0.15	0.34	0.36	0.36	0.36	0.39	0.39

Notes: This table presents the correlates of electricity sector TFP. The first column presents the bivariate correlation between electricity sector TFP and GDP per capita in log base 2, restricting the sample to the countries that have no missing values for any covariates. Column 2 includes the share of electricity output that is lost during transmission and distribution. We see that the relationship between electricity sector TFP and GDP per capita is completely mediated when we control for transmission and distribution losses. Electricity sector TFP and transmission and distribution losses are negatively correlated and transmission and distribution losses are negatively correlated with GDP per capita. These inferences are not affected by the inclusion of additional covariates. Additional covariates are added sequentially. We include the ruggedness of the land, the share of electricity capacity that is hydro, the average age of the electricity capital stock, and the area of the country. Estimates are also robust to the inclusion of region fixed effects (column 7). Robust standard errors are reported in parentheses. Significance levels are indicated as * 0.10 ** 0.05 *** 0.01.

3. A Neoclassical Growth Model with Electricity

In this section, we develop a neoclassical model with an electricity sector, where electricity is modeled as a strong complement to other inputs. To account for the various distortions on electricity provision and investment, we introduce wedges in both the input and output markets for power. The goal of the section (and the following one) is to assess whether there are significant long-run gains in GDP and consumption from raising electricity TFP to the world frontier or removing distortions in the sector.

3.1. Preferences and Technology

The economy is inhabited by a representative household that chooses consumption and investment each period to maximize its utility:

$$\sum_{t=0}^{\infty} \beta^t u(C_t) \tag{2}$$

where $\beta \in (0,1)$ is the discount factor, C_t is consumption, and $u(\cdot)$ is a flow utility function that is concave, strictly increasing, and continuously differentiable.

The representative household inelastically supplies one unit of labor each period for wage income. It also saves in the form of capital that can be used for the production of both electricity and non-electricity intermediate goods. The economy's capital stock evolves according to:

$$K_{t+1} = (1-\delta)K_t + I_t \tag{3}$$

where δ is the rate of depreciation and I_t is the quantity of final goods invested.

There is a single final good that serves as the numeraire in the economy. The final good is produced using electricity and non-electricity inputs by a representative firm facing competitive prices. The production technology is

$$Y_t = \left(\alpha E_t^{\frac{\sigma-1}{\sigma}} + (1-\alpha) X_t^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}, \tag{4}$$

where E_t and X_t denote respectively the amount of electricity and non-electricity inputs used. The elasticity of substitution between the two types of inputs is denoted by σ, and α reflects the importance of electricity in the production of final goods.

The non-electricity sector produces with the standard Cobb-Douglas technology

$$X_t = A_{X,t} K_{X,t}^{\theta_X} L_{X,t}^{1-\theta_X}, \tag{5}$$

where θ_X indicates the importance of capital. Likewise, the electricity sector also uses capital and labor to produce electricity, but with a different level of capital intensity θ_E:

$$E_t = A_{E,t} K_{E,t}^{\theta_E} L_{E,t}^{1-\theta_E}. \tag{6}$$

We omit fuel from the model for simplicity, as we found it had little impact on our quantitative conclusions.

3.2. Distortions in the Electricity Sector

We allow for wedges in both the input and output markets for electricity. The government may exogenously distort the market for grid capital by imposing a tax or providing subsidies at a rate τ_E^K. The electricity firm takes the output price $P_{E,t}$, wage rate w_t, rental rate of capital R_t, and capital distortion τ_E^K as given, and chooses its input bundle to solve

$$\max_{K_{E,t}, L_{E,t}} P_{E,t} E_t - w_t L_{E,t} - (1 + \tau_E^K) R_t K_{E,t}. \tag{7}$$

Note that τ_E^K may be negative when electricity capital is subsidized, which would make the electricity price lower than the frictionless level.

The non-electricity sector is competitive, so the representative firm solves a standard problem:

$$\max_{K_{X,t}, L_{X,t}} P_{X,t} X_t - w_t L_{X,t} - R_t K_{X,t}. \tag{8}$$

The representative final goods producer faces distortions in obtaining electricity. Specifically, it solves

$$\max_{E_t, X_t} Y_t - (1 + \tau_E) P_{E,t} E_t - P_{X,t} X_t \tag{9}$$

so that the costs of obtaining power may exceed the sales price of electricity by a factor of $(1 + \tau_E)$. We interpret this wedge broadly to include various types of distortion, such as the losses from interrupted production during outages or extra costs from self-generated power for firms with generators. If there is no friction in obtaining power, the final goods producer may achieve its full output level. With positive frictions, the final goods producer becomes less productive and cannot attain its maximum output level with the same input bundle. By construction, this wedge captures factors that reduce aggregate productivity by idling or wasting resources. Therefore, the distorted amount is not counted as value added by any firm in the economy.

We close the model with the representative household's budget constraint. The household collects income from labor and capital, plus the net transfers associated with the government's intervention in electricity capital. Mathematically, the household's constraint is

$$C_t + I_t \leq w_t + R_t(K_{X,t} + K_{E,t}) + \tau_E^K R_t K_{E,t}. \tag{10}$$

With final goods being the numeraire, the steady state of the economy is defined by a set of prices $\{w, R, P_E, P_X\}$ and quantities $\{C, I, L_E, L_X, K_E, K_X, E, X, Y\}$ that are consistent with the above problems, technologies, and constraints. We drop all time subscripts from now on, since we consider only the steady-state impacts of TFP changes in the economy.

3.3. Aggregate Effects of Improving the Electricity Sector

How should we think of the aggregate gains from improving the electricity sector? A natural point of departure is the seminal theorem by Hulten (1978), which states that TFP improvements at the sector level would translate into aggregate gains by a factor equal to the sector's Domar weight – its revenue as a share of GDP. Although the original Hulten's theorem requires certain assumptions such as the absence of frictions and unitary elasticity of substitution, it allows for computing the aggregate gains without complex calculation or numerical exercises. Therefore, we adopt the prediction with Hulten's theorem as a benchmark – if the aggregate gains predicted by our model exceed Hulten's prediction in most countries, we say that electricity behaves like a weak-link sector.

To apply Hulten's theorem, we need to clarify how GDP and Domar weights are measured in the economy. First, the government's interference with the rents for electricity capital is included in value added. This means the sector's value added equals its proceeds. We then consider the frictions in obtaining electricity. As explained after equation (9), we interpret the output wedge as a reflection of reduced aggregate productivity due to grid failure and therefore exclude the distorted amount from GDP. As a result,

$$GDP = w + R(K_X + K_E) + \tau_E^K R K_E = Y - \tau_E P_E E = C + I, \tag{11}$$

where the three equal expressions correspond to aggregate income, value added, and expenditure of the economy, respectively.

Using the value added method, the Domar weight of the electricity sector is

$$\lambda_E \equiv \frac{P_E E}{Y - \tau_E P_E E}. \tag{12}$$

According to Hulten's theorem, the first-order approximation of the aggregate gains brought by a one-percent increase in electricity TFP would be λ_E percent. Mathematically,

$$\frac{d\ln GDP}{d\ln A_E} \approx \lambda_E. \tag{13}$$

3.4. An Analytical Version

Before calibrating the full model, we consider a pair of simplifying assumptions that help clarify the main forces underlying the model and the conditions under which electricity is a weak link. First, we simplify electricity production to make it linear in capital (i.e., $\theta_E = 1$ and $E = A_E K_E$), since labor's share of revenue is small, as documented earlier. Linearity makes the output and input wedges equivalent in their effects on electricity prices, so we use only τ_E to denote the distortions, which are rebated to the household for simplicity. Second, we take the strong complementarity between electricity and non-electricity to the limit and assume a Leontief structure. With these simplifications, we can derive an analytical expression for the aggregate gains to contrast with the Domar weight for the electricity sector.

Given the simplified production functions, we can write the production function of final goods directly in terms of capital:

$$Y = \min\{\mu E, X\} = \min\{\mu A_E K_E, A_X K_X^{\theta_X}\}. \tag{14}$$

Labor does not appear explicitly because it has a unit measure and is entirely employed in non-electricity. The prices paid by the final goods producer for the two types of input are

$$P_E = \frac{R}{A_E} \tag{15}$$

and

$$P_X = \frac{R}{A_X \theta_X} K_X^{\theta_X - 1}, \tag{16}$$

respectively. The final goods producer then solves the problem

$$\max_{K_E, K_X} \left[\min\{\mu A_E K_E, A_X K_X^{\theta_X}\} - (1+\tau_E) R K_E - \frac{R}{\theta_X} K_X \right]. \tag{17}$$

The Leontief structure implies the optimality condition

$$K_X = \left(\frac{\mu A_E K_E}{A_X} \right)^{\frac{1}{\theta_X}}, \tag{18}$$

and the problem can be reduced to

$$\max_{K_E} \mu A_E K_E - (1+\tau_E)RK_E - \frac{R}{\theta_X}\left(\frac{\mu A_E K_E}{A_X}\right)^{\frac{1}{\theta_X}}. \tag{19}$$

The first order condition of this reduced problem requires

$$\mu A_E = R\left[1+\tau_E+\frac{1}{\theta_X^2}\left(\frac{\mu A_E}{A_X}\right)^{\frac{1}{\theta_X}} K_E^{\frac{1-\theta_X}{\theta_X}}\right], \tag{20}$$

so that

$$K_E = \left[\left(\frac{\mu A_E}{R}-1-\tau_E\right)\theta_X^2\right]^{\frac{\theta_X}{1-\theta_X}}\left(\frac{A_X}{\mu A_E}\right)^{\frac{1}{1-\theta_X}}, \tag{21}$$

$$K_X = \left[\left(\frac{\mu A_E}{R}-1-\tau_E\right)\theta_X^2\right]^{\frac{1}{1-\theta_X}}\left(\frac{A_X}{\mu A_E}\right)^{\frac{1}{1-\theta_X}}, \tag{22}$$

and

$$Y = \mu A_E K_E = \left[\left(1-\frac{(1+\tau_E)R}{\mu A_E}\right)\frac{\theta_X^2}{R}\right]^{\frac{\theta_X}{1-\theta_X}} A_X^{\frac{1}{1-\theta_X}}. \tag{23}$$

The steady-state rental rate of capital is pinned down by the household's Euler equation and is given by the standard expression

$$R = \frac{1}{\beta} - 1 + \delta. \tag{24}$$

Since all distortions are rebated to the household, the aggregate steady-state GDP is simply Y. Its response to electricity TFP is thus

$$\frac{dY}{dA_E} = \frac{\theta_X}{1-\theta_X}\frac{Y}{A_E}\frac{(1+\tau_E)R}{\mu A_E-(1+\tau_E)R}. \tag{25}$$

We can then derive the elasticity of aggregate output with respect to electricity TFP as

$$\frac{d\ln Y}{d\ln A_E} = \frac{\theta_X}{1-\theta_X}\frac{(1+\tau_E)R}{\mu A_E-(1+\tau_E)R}. \tag{26}$$

Equation (26) provides a convenient analytical expression to illustrate the forces that can make electricity a weak link. The gains decrease with A_E and increase with τ_E, indicating that the sector is more likely to be a weak link in countries with low productivity in electricity or substantial power market distortions.

Equivalently, we can write equation (26) in terms of electricity prices. Substituting equation (15) into equation (26), we obtain

$$\frac{d\ln Y}{d\ln A_E} = \frac{\theta_X}{1-\theta_X}\frac{(1+\tau_E)P_E}{\mu-(1+\tau_E)P_E}. \tag{27}$$

In equation (27), P_E is the price received by the electricity firm, and $(1+\tau_E)P_E$ is the price paid by the user. The user price is capped at μ because the price of final goods is normalized to one, and at least $1/\mu$ units of electricity are required to produce one unit of final goods. If the user price of electricity exceeds μ, the production cost of final goods would be higher than their price, and no equilibrium would exist. Below this maximum level, the user price of electricity positively affects aggregate gains. A high electricity price implies that the final goods producer devotes most of its expenditure to electricity, limiting the maximum possible price of non-electricity inputs. The low price of non-electricity implies a high marginal product of capital in that sector, which is only consistent with a low capital stock and therefore limits aggregate output. When A_E rises, the user price of electricity falls, and the final goods producer can accept higher prices of non-electricity inputs, which encourages the non-electricity sector to expand. This effect becomes weaker if the user price of electricity were already low because the non-electricity sector would then be large and the marginal return to capital would be low.

We also note that the elasticity of aggregate output with respect to electricity TFP can be written in terms of the sector's Domar weight, which enables comparison with the prediction from Hulten's theorem. Conventionally, the Domar weight would include the markup and take the form

$$\tilde{\lambda}_E = \frac{(1+\tau_E)RK_E}{Y} = \frac{(1+\tau_E)RK_E}{\mu A_E K_E} = \frac{(1+\tau_E)R}{\mu A_E}, \tag{28}$$

as in Baqaee and Farhi (2020). We distinguish this expression from the Domar weight in the full model, which excludes distortions not observed in electricity output and price data. Intuitively, λ_E in the full model corresponds to the Domar weight observable in the data. In contrast, $\tilde{\lambda}_E$ in this analytical model is a theoretical Domar weight that reflects the actual costs of obtaining electricity.

Substituting equation (28) into equation (26), we obtain

$$\frac{d\ln Y}{d\ln A_E} = \frac{\theta_X}{1-\theta_X}\frac{\tilde{\lambda}_E}{1-\tilde{\lambda}_E}. \tag{29}$$

Equation (29) delivers two messages. First, the aggregate gains increase with the sector's Domar weight. This follows the intuition from equation (27), as a higher electricity price implies a larger Domar weight under complementarity. Second, aggregate gains are nonlinear in electricity's Domar weight. When $\tilde{\lambda}_E$ is close to 1, the economy allocates most of its resources to electricity, leaving little for non-electricity, so a slight improvement in electricity TFP can free up a substantial amount of capital for the non-electricity sector. When $\tilde{\lambda}_E$ is close to zero, by contrast, the non-electricity sector already uses a high level of capital. Further increases in capital then yield little additional output in that sector and, under complementarity, little gain for the aggregate economy.

It is worth noting that the nonlinearity with respect to the Domar weight arises from a different channel than in Hulten's original expression. The canonical theorem treats all factors of production as exogenously endowed and thereby excludes the channel of capital adjustment. In our analytical model, however, the perfect complementarity between electricity and non-electricity inputs implies that the first-order gains are zero. All aggregate gains, therefore, come from the reallocation and the long-run stock change in capital.

Baqaee and Malmberg (2025) extends Hulten's theorem to a dynamic setup and amends the formula for predicting long-run aggregate gains. Applying their formula, we have the equation

$$\frac{d\ln Y}{d\ln A_E} = \lambda_E + \frac{RK}{Y}\frac{d\ln K}{d\ln A_E}. \tag{30}$$

Compared to the canonical Hulten's theorem, the additional term says that the long-run gains depend on how the capital stock responds to sector-level shocks. If the capital stock grows, the aggregate output gains will be larger than predicted by the static Hulten formula, and vice versa. Moreover, the effect of capital accumulation depends on the importance of capital as a factor of production. The same response in long-run capital stock will generate a larger impact on the long-run aggregate output if a larger share of national income goes to capital.

This equation based on Baqaee and Malmberg (2025) illustrates why the gains shown in equations (26), (27), and (29) all increase in θ_X. With the grid using only capital, θ_X effectively controls the share of national income going to capital. When θ_X is large, capital is intensively used in the non-electricity sector and accounts for a larger share of national income. There will be a significant reallocation of capital from electricity to non-electricity in the long run following an increase in A_E, incentivized by the greater marginal product to capital implied by a large θ_X. If the non-electricity sector does not use capital (i.e., $\theta_X = 0$), then any improvement in the electricity sector will not affect the non-electricity sector, and aggregate output would be constrained by the perfect complementarity between the two sectors. In such a case, improvements in A_E would only lead to a lower capital stock in equilibrium, but with no gains in aggregate output.

Analytically, we can derive from equations (21) and (22) that

$$K = K_E + K_X = \left(\frac{A_X}{\mu A_E}\right)^{\frac{1}{1-\theta_X}} \left[(\mu A_E - (1+\tau_E)R)\frac{\theta_X^2}{R}\right]^{\frac{\theta_X}{1-\theta_X}} \left[1 + (\mu A_E - (1+\tau_E)R)\frac{\theta_X^2}{R}\right], \tag{31}$$

which implies that

$$\frac{d\ln K}{d\ln A_E} = -\frac{1}{1-\theta_X} + \frac{\theta_X}{1-\theta_X}\frac{\mu A_E}{\mu A_E-(1+\tau_E)R} + \frac{\theta_X^2\mu A_E}{\theta_X^2\mu A_E+(1-\theta_X^2(1+\tau_E))R}. \tag{32}$$

Although it is not straightforward to see how the total capital stock responds to changes in A_E, the limiting cases provide useful illustrations. When a country is extremely productive in power,

$$\lim_{A_E\to\infty}\frac{d\ln K}{d\ln A_E} = -\frac{1}{1-\theta_X} + \frac{\theta_X}{1-\theta_X} + 1 = 0, \tag{33}$$

meaning that capital will not adjust, and thus will not contribute to aggregate gains. When a country is so unproductive in power that its A_E barely sustains its economy,

$$\lim_{A_E\to\frac{(1+\tau_E)R}{\mu}}\frac{d\ln K}{d\ln A_E} = \infty, \tag{34}$$

meaning that any small improvement in A_E will lead to huge responses in capital stock, generating considerable gains in aggregate output.

The discussion above illustrates that a key determinant of the aggregate gains, compared to Hulten's predictions, is whether the increase in electricity TFP induces the use of more capital in the non-electricity sector than the amount of capital saved in electricity. A key factor is θ_X, capital's intensity in non-electricity. In fact, we derive from equation (29) that the aggregate gains exceed Hulten's prediction under the condition

$$\tilde{\lambda}_E > \frac{1-2\theta_X}{1-\theta_X}, \tag{35}$$

which is more easily satisfied with a higher θ_X. With a high marginal product of capital, the non-electricity sector would have a strong incentive to rent more capital when the electricity sector needs less.

One limitation of this expression is that the Domar weight of electricity includes distortions that are not directly or precisely observed. Distortions that increase power costs, such as outages, power rationing, and higher self-generation costs, can lower recorded electricity output and thus lower the observed Domar weight. It is therefore more useful to rewrite this condition into

$$A_E < \frac{(1+\tau_E)R}{\mu}\frac{1-\theta_X}{1-2\theta_X}, \tag{36}$$

which highlights that the TFP level of the electricity sector, A_E, is the crucial factor. This inequality underscores the importance of our empirical exercise, which estimates A_E by country. Without an accurate measure of the TFP, there could be various combinations of A_E and τ_E that satisfy (36) and at the same time rationalize low observed Domar weights of the sector.

4. Quantifying Whether Electricity is a Weak Link

The analytical model provides basic intuition for what makes electricity a weak link. We now calibrate the full model and use it to ask whether electricity is a weak link for development once calibrated to the cross-country evidence from above and other key aggregate moments.

4.1. Calibration

The calibration involves parameters that are common across countries and those that are specific to each country. The discount factor β, the depreciation rate δ, the elasticity of substitution between power and non-power inputs σ, the capital intensity of the non-electricity sector θ_X, and the capital intensity of the electricity sector θ_E are held constant for all countries. The sector-specific TFP A_X and A_E, the level shifter α in the final goods production function, and the output and input distortions in electricity τ_E and τ_E^K are allowed to vary across countries.

Table 3 illustrates the calibration strategy and results. All common parameters are externally calibrated with the listed sources. The TFP of the electricity sector is based on our estimates in section 2. The TFP of the non-electricity sector A_X, the level shifter α, and the input distortion for electricity τ_E^K are jointly calibrated to match GDP per capita, the observed Domar weight for electricity, and the capital-labor ratio.[8] To compute the Domar weight for the grid, we use the output by the grid from section 2 and the power price from the World Bank Doing Business dataset. The Domar weight is computed as the value of grid power output, less transmission and distribution loss, divided by the country's current GDP.

Frictions in the output market, τ_E, are aggregated from exogenously calibrated frictions for firms with and without access to generators. We first obtain data on annual outage hours from the World Bank's Doing Business dataset and divide them by the annual working hours per worker compiled in Bick, Fuchs-Schündeln and Lagakos (2018) to obtain the share of working hours affected by outages, denoted by ω. Firms with access to generators obtain power at a higher cost ϕ times that of grid power. We let $\phi = 4.35$, which is the average cost ratio of self-generated power to grid power computed from data in Trimble et al. (2016) and World Bank (2007). Therefore, firms with access to generators pay a higher average cost that is $1 + \tau_{E,gen} = \omega\phi + (1 - \omega)$ times the grid

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[8] We normalize the capital-labor ratio in electricity for the U.K. for its deregulated power sector. That is, $\tau_E^K = 0$ for the U.K. For other countries, τ_E^K is calibrated so that the model matches the country's capital-labor ratio in electricity relative to the U.K. level.

Table 3: Model Parameterization

Parameter	Interpretation	Value	Source/Target
A. Externally Determined			
β	Discount factor	0.96	Comin et al. (2021)
δ	Depreciation rate of capital	0.06	Hall and Jones (1999)
θ_X	Capital intensity in non-electricity	1/3	Hall and Jones (1999)
θ_E	Capital intensity in electricity	0.93	Data on labor share
σ	EoS between power & non-power input	0.2	Berndt and Wood (1975)
A_E	TFP of electricity sector	Various	Estimated grid TFP
τ_E	Wedges over electricity prices	Various	See text
B. Internally & Jointly Calibrated			
α	Weight on non-power inputs	Various	Domar weight of the grid
A_X	TFP of non-power input	Various	GDP per capita
τ_E^K	Wedges over grid capital costs	Various	K/L ratio in electricity

Notes: This table reports the parameters of the model that are externally determined (Panel A) and jointly calibrated (Panel B). The first five – β, δ, θ_X, θ_E, and σ – are country invariant. The rest vary by country.

price, which defines $\tau_{E,gen}$:

$$\tau_{E,gen} = \omega(\phi - 1). \tag{37}$$

For firms without access to generators, we assume that production stalls during outages. These firms cannot achieve their full production capacity, and their final output is a fraction $1-\omega$ of their potential output. We assume that the fraction of output forgone during outages is equal in level to the electricity output market frictions, so that

$$\tau_{E,nogen} P_E E = \omega Y. \tag{38}$$

We note that the value added by a firm without generators is $(1-\omega)Y$. Therefore,

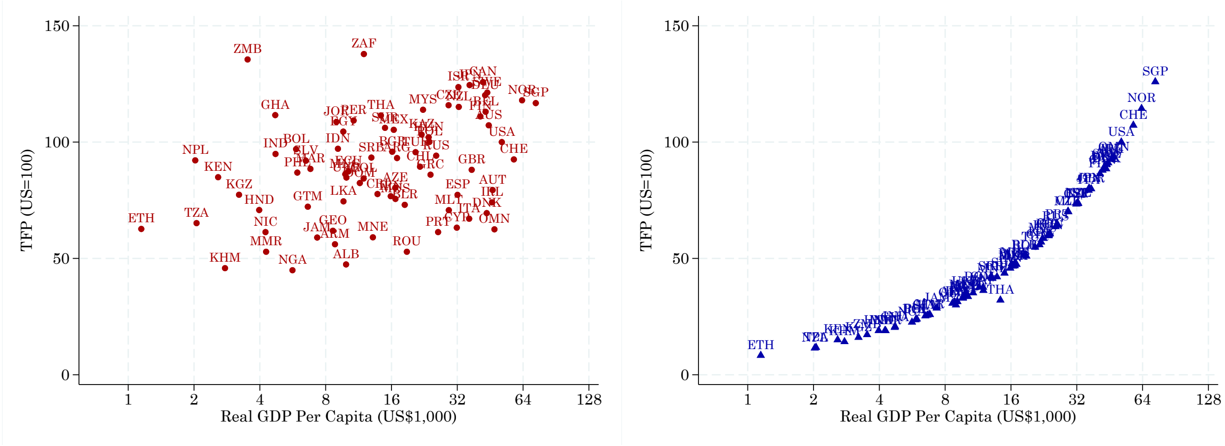
$$\tau_{E,nogen} = \frac{\omega}{(1-\omega)\lambda_E}. \tag{39}$$

The World Bank Enterprise Survey provides data on the share of firms with generators. We denote this share by γ and compute the country-level τ_E as

$$\tau_E = \gamma \tau_{E,gen} + (1-\gamma)\tau_{E,nogen}. \tag{40}$$

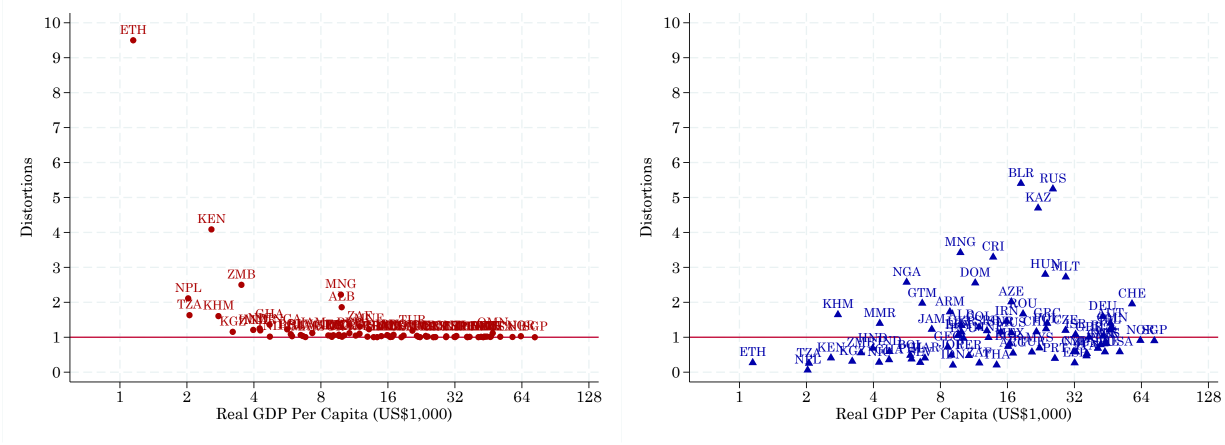
Figure 3 shows the calibrated levels of sectoral productivity and wedges. The sub-figures 3a and

Figure 3: Calibrated Sectoral TFP and Distortions



(a) TFP in Electricity

(b) TFP in Non-Electricity



(c) Output Distortion

(d) Input Distortion

Note: This figure plots the model's TFP in electricity (A_E), TFP in non-electricity (A_X), output distortion in electricity (τ_E), and input distortion in electricity (τ_K).

3b show much larger variation in A_X across countries than in A_E, consistent with Figure 2. The sub-figure 3c plots the gross output wedges, $1+\tau_E$, and compares them to the frictionless level at one. Several developing countries have high output wedges due to low shares of generator ownership or long outages, such as Ethiopia, Kenya, and Zambia. Most countries (particularly the richer ones) have output wedges not too far from the frictionless case.

The sub-figure 3d plots the gross input wedges $1+\tau_E^K$ implied by the capital-labor ratio of electricity. Nearly half of the countries have input wedges below 1, indicating that they have a higher capital-labor ratio in electricity than the U.K., and may thus be interpreted as subsidizing electricity capital in the model. We view these positive input wedges as consistent with the significant international support for electricity provision provided by organizations like the World Bank.

4.2. Fit of the Calibrated Model

We examine the fit of the calibrated model against several non-targeted moments. Figure 4 shows that the model matches the cross-country patterns of these moments quite well. Sub-figures 4a and 4b show that the patterns of electricity labor and capital productivity are well matched, supporting the use of a Cobb-Douglas technology with constant (and very high) capital share across countries. Sub-figure 4c shows that our model not only fits the upward-sloping trend of the electricity employment share, but also replicates a hump-shaped pattern whereby some middle-income countries hire workers in electricity above the trend.

Sub-figure 4d shows a good match to the cross-country dispersion of the aggregate capital-labor ratio. In sub-figure 4e, we plot the ratio of electricity capital to the total number of workers in the economy. Although the model-generated numbers are a little more dispersed than those in the data, they fit the upward trend and suggest that the model captures the importance of the electricity sector in aggregate production rather well. Finally, we note that the ratio of electricity capital to GDP is highly dispersed across the world income distribution, and neither the model nor data feature a correlation between the electricity capital-to-GDP ratio and GDP per capita.[9]

4.3. Long-Run GDP Gains from Raising TFP in Electricity

With the calibrated benchmark, we assesses whether improving the TFP of the electricity sector brings aggregate gains that are large in an absolute sense or larger than those predicted by Hulten's theorem. We raise each country's A_E to the world frontier level, defined as the 90th percentile of A_E to rule out outliers. The average increase is 45 percent for the entire sample and 60 percent for countries in the lower half of the income distribution. Holding all other parameters unchanged, we compute a new steady state for each country and calculate the gains in its aggregate output. We refer to this experiment as the baseline exercise. To observe the effect on developing countries more clearly, we plot only countries in the lower half of the world income distribution.

Figure 5 plots the changes in GDP generated by the model versus those calculated with Hulten's theorem. The x-axis plots Hulten's predictions, while the y-axis corresponds to the model-predicted gains. The solid 45-degree line separates the plot, and observations above it show aggregate gains *higher* than Hulten's predictions. Ethiopia and Kenya comfortably beat Hulten predictions, with GDP gains of around 4 percent relative to a predicted 1 percent or less. Several other developing countries also lie above the solid line, but their gains do not exceed Hulten's predictions by as

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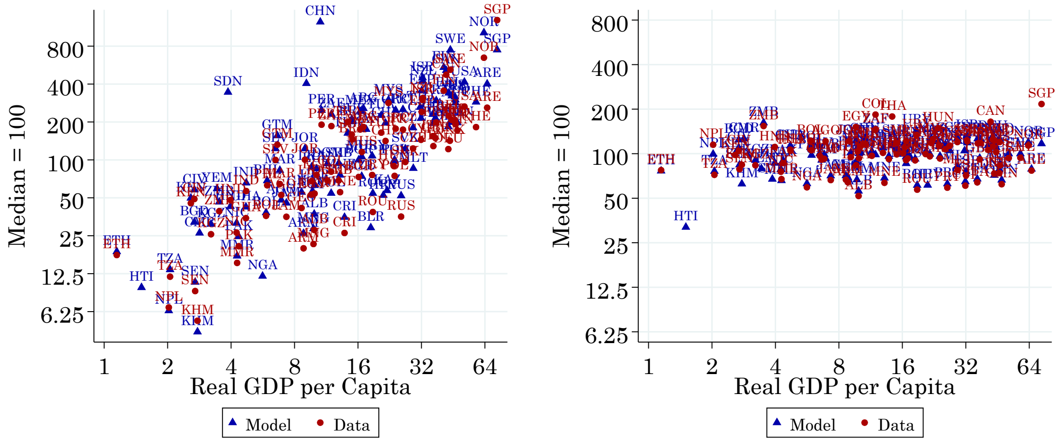
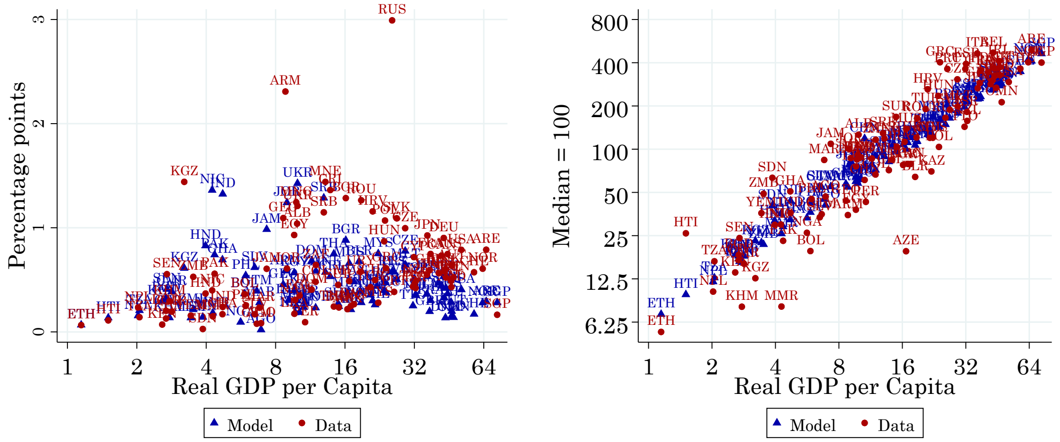
[9] One other moment not plotted here is the price of electricity in the model and data. These data (which come from the IEA) have limited covereage in developing countries and may not correspond closely to prices that firms there actually pay in practice. Still, the model and data show a reasonable correspondence, with higher measured electricity prices in poor countries in the both the model and data. See Appendix Figure A3.

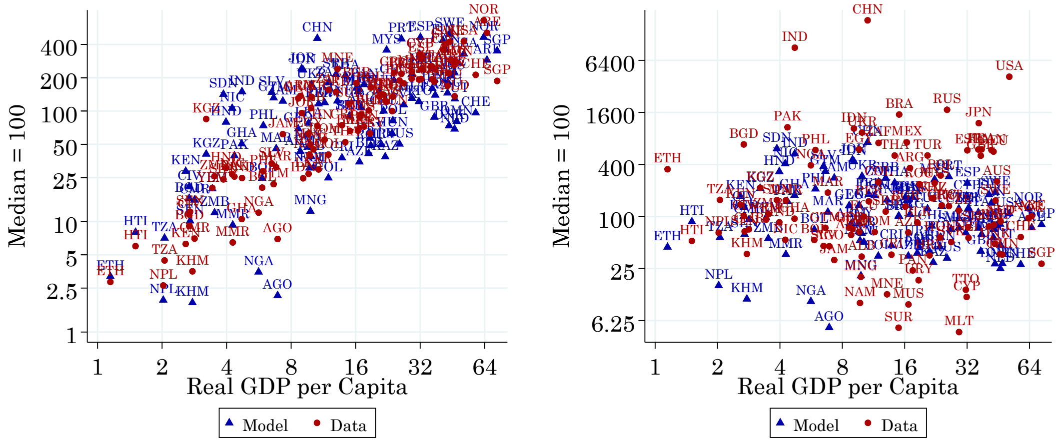
Figure 4: Model Fit to Non-Targeted Moments



(a) E/L_E (b) E/K_E



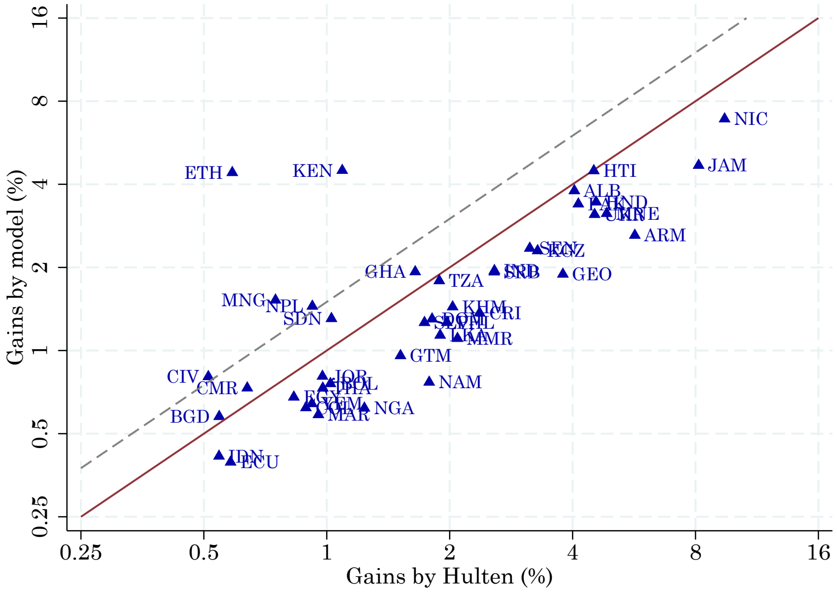
(c) Employment Share in Electricity (d) Aggregate K/L



(e) K_E/L (f) K_E/GDP

Note: This figure plots the model's predictions for six non-targeted moments and the data counterparts against GDP per capita.

Figure 5: Long-Run GDP Gains from Raising Electricity TFP to the Frontier



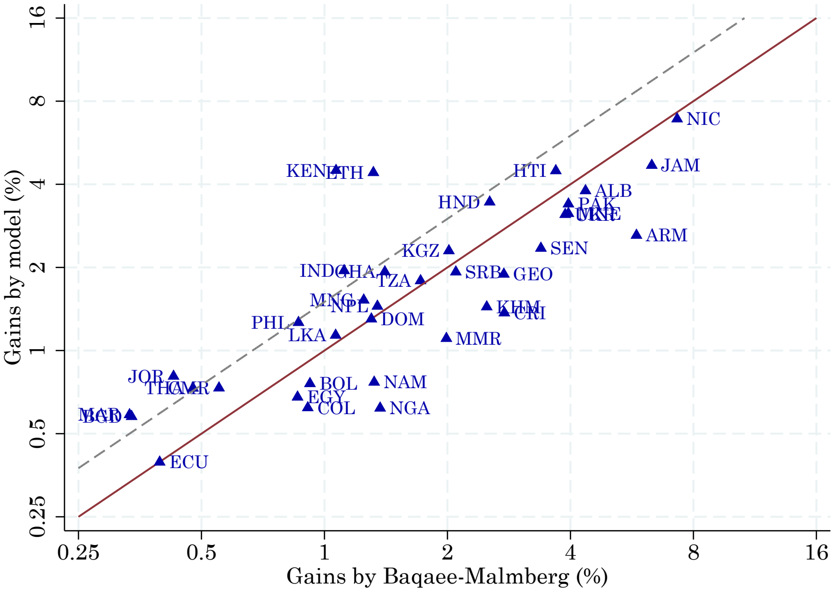
Note: This figure plots the model's predicted long-run GDP gains from raising A_E to the world frontier in each developing country, defined to be countries in the bottom half of the world income distribution. The x-axis plots the GDP gains predicted by Hulten, as a frame of reference. The y-axis plots the model's predicted GDP gains. The red solid line represents $y = x$, and the black dashed line represents $y = 1.5x$, which captures the model's predictions being equal to 1.5 times those of Hulten. Angola, China, Peru, Suriname, South Africa, and Zambia are not shown in the figure because their gains are too small (<0.1 percent). None of these countries derive higher gains than Hulten's predictions.

much. The dashed line represents 1.5 times Hulten's predicted gains. Mongolia, Nepal, and Côte d'Ivoire lie above this line, though their gains are modest in an absolute sense, maxing out below 2 percent of GDP. The vast majority of developing countries lie below the 45-degree line, and hence derive gains that are even smaller than suggested by Hulten. Overall, this figure provides very little support for the conclusion electricity is a weak-link in the developing world.

Why do the gains fall short of Hulten's predictions? Several forces are at work. First, Hulten's predictions would be exact if the elasticity of substitution between inputs were unitary, but this is not the case with electricity. As noted in the analytical model, perfect complementarity between the intermediate inputs would yield zero gains in aggregate output, absent factor reallocation and adjustments to the capital stock. In the calibrated model, the low elasticity of substitution ($\sigma = 0.2$) between electricity and non-electricity allows for some first-order gains, but only to a limited extent. Therefore, most of the gains in the model come from the reallocation of factors — primarily capital — and from long-run adjustments to the capital stock.

However, capital reallocation may not yield substantial gains due to low TFP in the non-electricity

Figure 6: Long-Run GDP Gains from Raising Electricity TFP Relative to Baqaee-Malmberg



Notes: This figure plots the model's predicted long-run GDP gains from raising A_E to the world frontier in each developing country, defined to be countries in the bottom half of the world income distribution. The x-axis plots the GDP gains predicted by Baqaee and Malmberg (2025), as a frame of reference. The y-axis plots the model's predicted GDP gains. The red solid line represents $y = x$, and the black dashed line represents $y = 1.5x$, which captures the model's predictions being equal to and 1.5 times those of Baqaee and Malmberg (2025). Angola, China, Côte d'Ivoire, Guatemala, Indonesia, Peru, Sudan, Slovenia, Suriname, Yemen, South Africa, and Zambia are not shown in the figure because they do fit comfortably on the graphl; none of the excluded countries gains more than 1.5 percent.

sector. Because θ_X is much lower than θ_E, the non-electricity sector exhibits stronger decreasing returns to capital than electricity. With low A_X on top of decreasing returns, generating a substantial increase in non-electricity output (and hence higher GDP) would require much larger capital reallocation. As noted in the model section, this channel is considered by Baqaee and Malmberg (2025), and we apply equation (30) to examine the importance of capital adjustment for aggregate gains. We compute the derivative of $\ln K$ with respect to $\ln A_E$ as the ratio of the percentage changes in capital stock to electricity TFP. We plot these Baqaee-Malmberg predictions along the x- axis in Figure 6.

Figure 6 shows that 17 countries are located above the solid 45-degree line, achieving higher gains than predicted by the Baqaee-Malmberg formula. Ethiopia and Kenya again stand out as the countries whose gains most exceed the theoretical benchmark. However, the number of countries with gains that substantially exceed the predicted values remains limited, as shown by the few observations narrowly above the dashed line. What really matters for welfare is consumption, and Baqaee and Malmberg (2025) also provide a formula for predicting consumption gains. Our simulation shows that the long-run gains in consumption average 1.9 percent while the Baqaee-Malmberg formula predicts 2.1 percent. The number of countries achieving greater consumption gains than predicted by the Baqaee-Malmberg formula is smaller than the number achieving greater output gains than predicted. See Appendix Figure A4. These comparisons continue to provide scant support for the statement that electricity is a weak link in the developing world.

4.4. Long-Run GDP Gains from Removing Distortions

We now examine the aggregate response to reducing frictions in the electricity sector. In Figure 7a, we plot these gains from removing the output wedges against our baseline gains. The gains from the baseline exercise are shown on the horizontal axis, and the gains from removing the output wedges are displayed on the vertical axis. Kenya and Ethiopia continue to stand out with double-digit gains in aggregate output, consistent with the fact that they have the longest outages in the sample. Several other countries — such as Albania, Ghana, Haiti, Mongolia, and Zambia — also gain more from removing the output wedges than from higher electricity TFP, as they also belong to the top decile in outage hours. Overall, however, the gains are limited for countries with less severe outage problems. The average gains are 2.2 percent for developing countries, only modestly higher than the 1.7 percent increase in the baseline exercise. This result suggests that reducing output-market frictions offers only a modest improvement over raising electricity TFP for the average developing country.[10]

We then explore the role of input wedges. As suggested by the calibrated values of τ_E^K, many countries are subsidizing the grid. Figure 7 shows that removing the subsidies would lead to substantial output loss for almost all developing countries. This result stems from the fact that countries face distortions in both the electricity input and output markets. Given only the output-market distortions, the supply of power would be less than in an efficient economy. Subsidizing the grid is one way to restore power supply toward the efficient level. Therefore, removing the subsidies can reduce power supply, and hence aggregate output. To verify this explanation, we compare the changes in both aggregate output and consumption to the case where we remove all wedges. We calculate average losses of 4.0 percent in GDP and 2.2 percent in consumption from removing the input wedges alone. Nevertheless, removing both the input and output wedges leads to a small 0.7 percent loss in output but a 1.1 percent increase in consumption. These numbers confirm that investment subsidies serve to partially offset the distortions in the output market.

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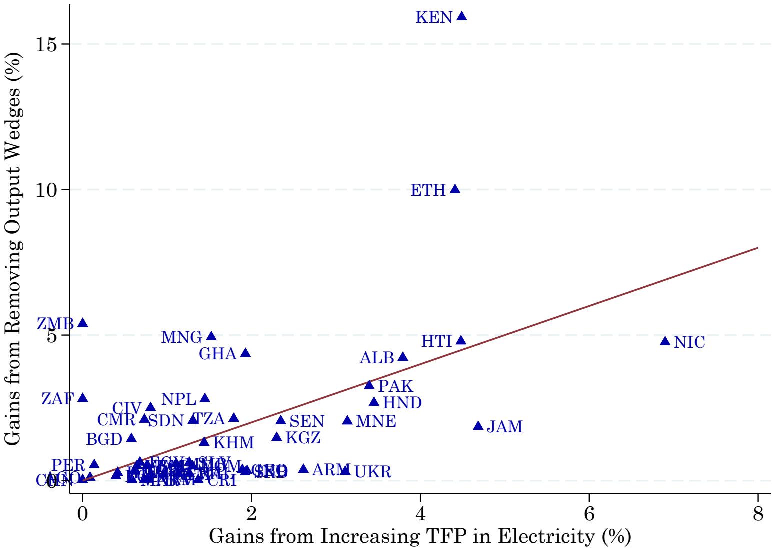
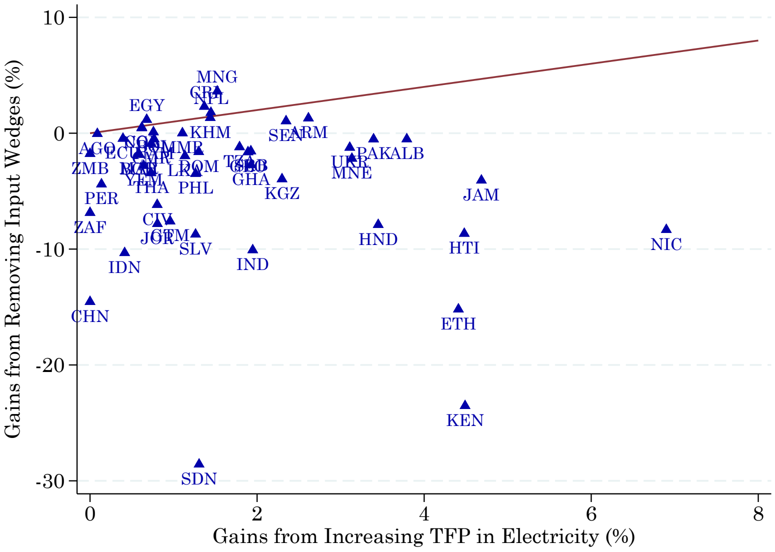
[10] We also built and calibrated a version of the model with endogenous outages through power rationing, similar to the model of Fried and Lagakos (2023). This version of the model is less parsimonious than the one presented in the paper but still does not present a strong case for electricity being a weak link outside of Ethiopia and Kenya. Details are available on request.

Figure 7: Long-Run GDP Gains from Removing Distortions on Electricity



(a) Removing Output Distortions



(b) Removing Input Distortions

Notes: This figure plots the model's predicted long-run GDP gains from removing wedges in the electricity market in each developing country, defined to be countries in the bottom half of the world income distribution. The x-axis plots the GDP gains from the baseline exercise. The y-axis plots the gains from removing wedges. Sub-figure (a) compares the gains from removing output wedges to the gains from raising electricity TFP. Sub-figure (b) compares the gains from removing input wedges to the gains from raising electricity TFP. The solid red line represents $y = x$, which equates the gains from removing wedges to those from the baseline exercise.

5. When *Can* Electricity Be a Weak Link?

Our quantitative model predicts that electricity is not likely to be a weak link in the development of low-income countries. Neither raising electricity TFP to the frontier nor removing distortions in the electricity sector yields long-run GDP gains that are large in an absolute sense, or relative to the simple Hulten benchmark or the more sophisticated Baqaee-Malmberg one. Is this conclusion hard-wired into the model? Or is it a result of some aspect of the data? To answer this question, we explore alternative calibrations and counterfactual simulations that help illustrate how the data inform the predictons of the previous section.

5.1. Negative Shocks

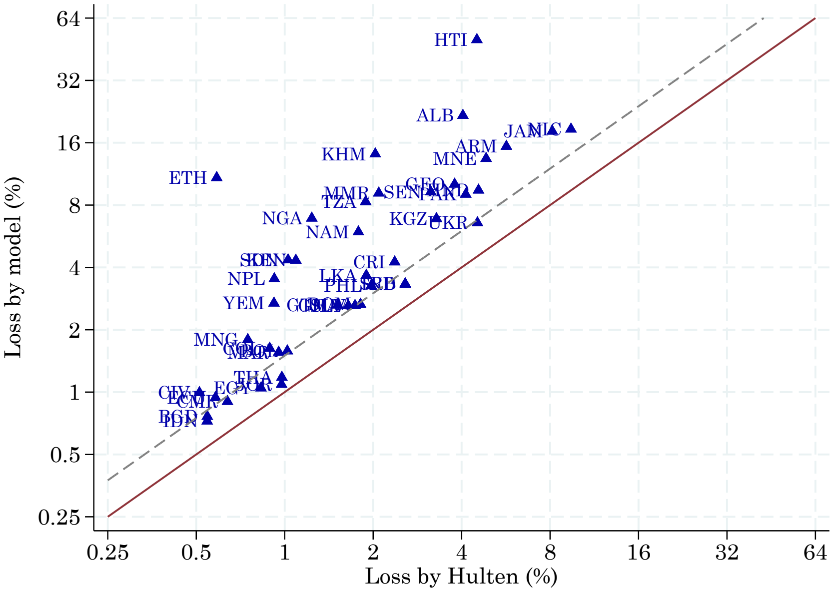
We note that most of the macroeconomic literature on energy focuses on negative shocks. To give some recent examples, Leibovici and Santacreu (2020) model global shortages of essential goods following a global supply shock; Brooks and Donovan (2026) analyze how governments should respond to downstream effects on fertilizer markets; and Bachmann, Kuhn, Peichl, Baqaee, Loschel, Pittel, Bayer, Moll and Schularick (2022) simulate the effects of fossil fuel disruptions caused by Russia's invasion of Ukraine. To see such an impact, we reverse the main exercise and reduce each country's electricity TFP. Since a decrease in electricity TFP from grid failures is more likely a short-run phenomenon, we hold factor allocations fixed at their calibrated levels.

Figure 8 shows how destructive shocks to power generation can be for developing countries. Both axes show the *loss* in GDP in the short run, as predicted by Hulten (x-axis) and by our model (y-axis). All countries incur losses significantly higher than Hulten predicts, consistent with findings in the literature that disruptions in electricity production lead to severe negative short-run impacts on GDP. This result is also exactly as predicted by Baqaee and Farhi (2019), where a negative TFP shock to a sector generates larger short-run GDP losses than Hulten's theorem predicts when the sector has few substitutes. The overall lesson is that electricity not being a weak-link for development can be consistent with out-sized short-run damage caused by a negative electricity shock.

5.2. Counterfactually Low Electricity TFP

One could not have known ex ante that electricity would be a sector whose TFP is close to the frontier relative to that of other sectors. In this subsection, we explore what would happen had we found that A_E was significantly lower in poor countries. For this exercise, we set each country's electricity TFP to 5 percent of its estimated level, solve for the steady state, and then compute a counterfactual steady state by raising that TFP by the same multiple as in the baseline exercise.

Figure 8: GDP Loss from Reducing Electricity TFP



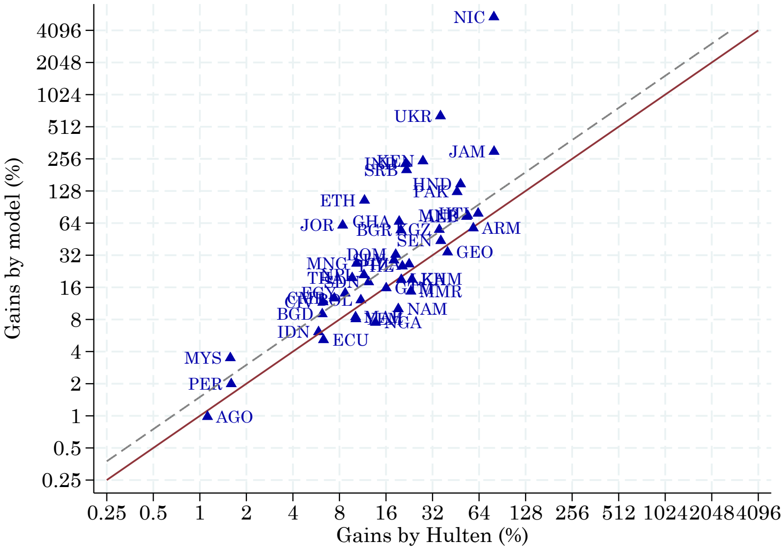
Notes: This figure plots the model's predicted short-run GDP loss from lowering electricity TFP by the same multiples in the baseline exercise for each developing country. The x-axis plots the loss predicted with Hulten's formula. The y-axis plots the loss computed with the model. The solid red line represents $y = x$, and the dashed line represents $y = 1.5x$, which captures the model's predictions being 1.5 times thoes of Hulten.

Figure 9 plots the gains from raising A_E from counterfactually low levels, showing that many more countries now gain substantially. Among developing countries, 33 of them now gain more than Hulten's predictions. Twenty lie above the dashed line, indicating gains more than 50 percent higher than Hulten's predictions. Furthermore, the same increases in A_E now generate substantially larger gains, more than doubling aggregate output in a number of developing countries.

Why do the same (percent) increases in A_E lead to such different gains in aggregate output? We examine these exercises more carefully by looking at sector-level variables in Table 4. Panel A shows the changes in steady-state variables before and after raising A_E to the world frontier. For the baseline exercise, an average 45 percent increase in A_E leads to only limited growth in non-electricity capital, together with a substantial decline in electricity capital. These changes are consistent with the interpretation that the marginal product of capital in non-electricity is so low that the best response to higher A_E is to reduce capital in the electricity sector rather than massively expand aggregate production. The gains in GDP are constrained by the limited increase in non-electricity inputs despite a larger increase in power supply.

In contrast, when A_E starts from 5 percent of the empirically estimated levels, the electricity sector can become the bottleneck for growth. In this scenario, the electricity sector would, on average,

Figure 9: Gains from Raising Electricity TFP Starting from Counterfactually Low Level



Notes: This figure plots the model's predicted long-run GDP gains from raising A_E by the same multiple as in the baseline exercise, but starting from 5% of the estimated values. The figure focuses on developing countries, defined to be those in the bottom half of the world income distribution. The *x*-axis plots the GDP gains predicted by Hulten, as a frame of reference. The *y*-axis plots the model's predicted GDP gains.

absorb 10.7 percent of total employment and have a Domar weight of 41.3 percent. As we raise A_E from this unproductive benchmark, capital accumulation becomes much more profitable. In the long-run, the stock of capital increases by a staggering 874 percent in the non-electricity sector, which is starting from minute levels. It does not make sense to invest a lot in capital, after all, if the electricity needed to run it is so dear. Aggregate capital increases by 69 percent, and this accumulation nearly doubles GDP – far more than Hulten's prediction of 17 percent. This counterfactual exercise echoes the result of analytical model that electricity can be a weak link when its TFP is small enough. It also underscores the importance of our cross-country estimates of electricity TFP for the paper's conclusions. One can get electricity to be a weak link in our model, in other words, but only at the cost of making highly inaccurate predictions relative to the data.

5.3. Non-Electricity TFP

The finding that electricity is not a weak link does not necessarily imply that improving the non-electricity sector would deliver better results. To determine which sector is a better target of focus for development policy, we next consider a similar exercise that keeps the TFP of the electricity sector unchanged while raising that of the non-electricity sector. As illustrated earlier, sectoral TFP levels are essential for determining aggregate gains. In the calibrated model, the greater

Table 4: Long-Run Effects of Raising Electricity TFP

Panel A: Changes in variables (%)	A_E	K_E	K_X	K	E	X	GDP	Hulten
Baseline	45	-21	2	-1.1	8.1	0.7	1.0	1.6
Low A_E counterfactual	45	50	874	69	99	51	93	17

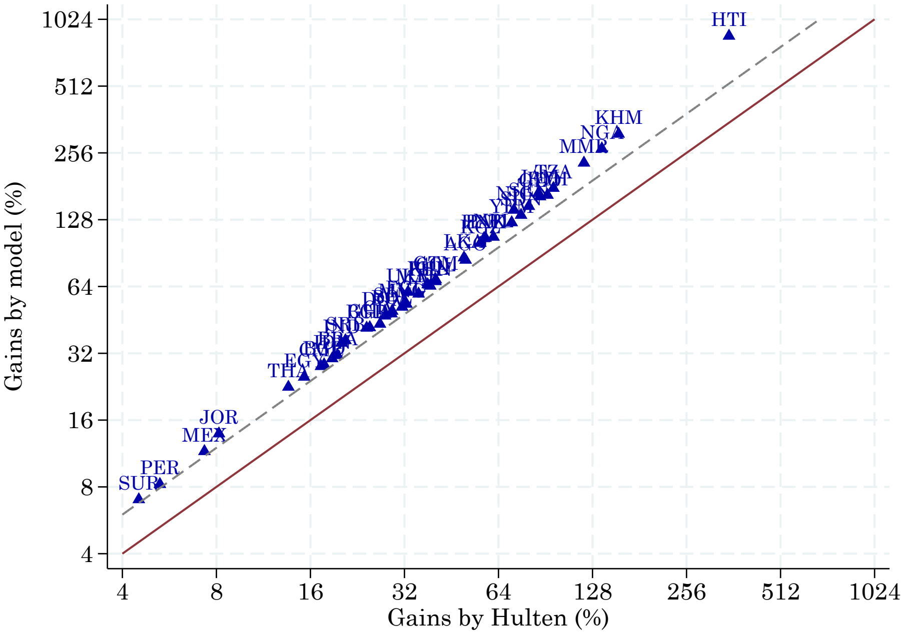
Panel B: Size of electricity sector (%)	Domar weight (λ_E)	Employment share (L_E)
Baseline	4.0	0.4
Low A_E counterfactual	41.3	10.7

*Notes:*This table reports the changes in steady-state variables when the TFP of the electricity sector is raised from different benchmark cases, with the last column recording the aggregate gains predicted using Hulten's theorem. The first row describes the baseline exercise as shown in Figure 5. The second row computes the changes from the same increase in A_E, but with its initial levels only set to only 5% of our estimate. All numbers are averages across countries, expressed in percentage points.

dispersion of A_X across countries leaves room for large gains as A_X increases. To make this exercise comparable to the baseline, we increase A_X for each country by the same factor as in the baseline exercise and examine the aggregate gains

Figure 10 plots the gains from raising non-electricity TFP against Hulten's predictions. In contrast to Figure 5, where most gains fall below the 45-degree line, all countries now enjoy higher gains than Hulten predicts. In fact, all countries in the lower half of the world income distribution gain more than 1.5 times Hulten's prediction. The higher TFP in the non-electricity sector encourages its use of capital to grow by 121 percent on average across those countries, and the average capital stock increases by 111 percent. As we stated above, one can not take these exercises seriously as "policy experiments." The point here is that, if anything, the non-electricity sector is a more promising candidate "weak link" than electricity.

Figure 10: Long-Run GDP Gains from Raising Non-Electricity TFP



Notes: This figure plots the model's predicted long-run GDP gains from raising A_X in each developing country by the same multiple for A_E in the baseline exercise. Developing countries are defined as those in the bottom half of the world income distribution. The x-axis plots the GDP gains predicted by Hulten, as a frame of reference. The y-axis plots the model's predicted GDP gains. The red solid line represents $y = x$, and the black dashed line represents $y = 1.5x$, which captures the model's predictions being equal to 1.5 times those of Hulten.

6. Conclusion

This paper examines whether the electricity sector can be considered a weak link in the development process. There are sensible reasons to think it can and should be. It is hard to find good substitutes for electricity in the production process, and most modern technologies rely crucially on electricity as an input. It is not surprising that electricity is the subject of much focus and funding by development institutions like the World Bank.

Despite the perceived importance of electricity, we find little evidence that it acts as a weak link across the developing world today. Empirically, we measure TFP in the electricity production and distribution sector for 100 countries and find less variation between low- and high-income countries than in aggregate TFP. In fact, many developing countries are already nearly as productive in electricity as advanced economies. Through the lens of a neoclassical growth model calibrated to these cross-country data, we show that the GDP gains from raising electricity TFP to the world frontier are generally modest in magnitude and small relative to simple benchmarks like Hulten's formula and its dynamic extension. A calibrated version of our model that does make electricity a weak link requires the sector to be counterfactually large and unproductive.

The broad policy implication of our analysis is that development spending based on the presumption that electricity is a binding constraint on growth may lead to disappointment. Electricity may well have been the bottleneck in the developing world in decades past, but nowadays our empirical and quantitative work suggests this is not the case. From an academic perspective, we welcome the continued search for other weak-link sectors, whether through new empirical evidence, novel modeling techniques, or both.

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Online Appendix for
“Is the Electricity Sector a Weak Link in Development?

April 22, 2026

by Jonathan Colmer, David Lagakos, Martin Shu

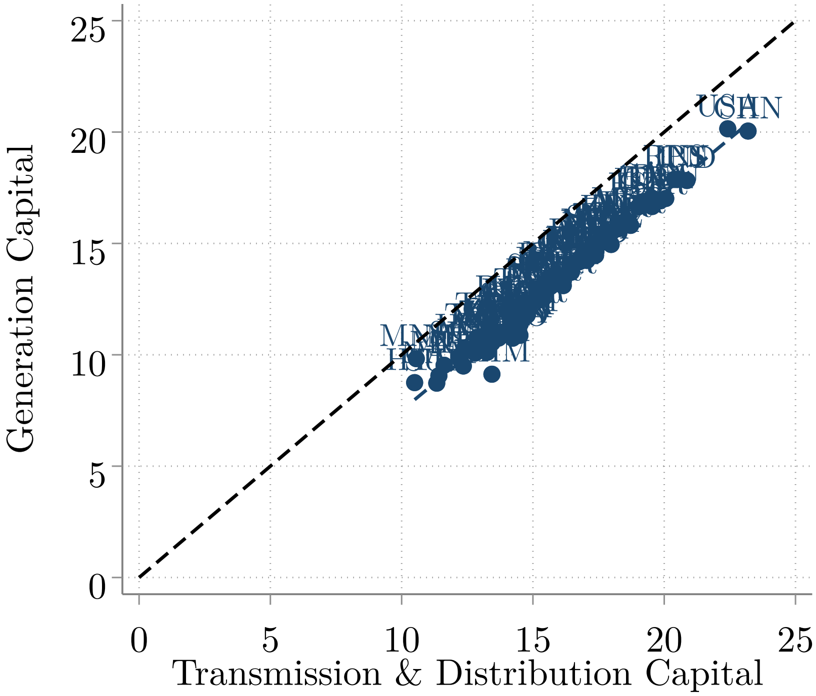
A. Additional Tables and Figures

Table A1: Electricity Productivity Summary Statistics

	Average			
	Labor Productivity (MWh / worker)			Real GDP Per Worker
	(1)	(2)	(3)	(4)
Bottom Quartile	490	390	360	6,124
Second Quartile	1,926	1,714	1,671	19,935
Third Quartile	1,635	1,445	1,475	43,314
Top Quartile	4,284	4,026	4,079	96,058
Top/Bottom	8.74	10.32	11.33	15.68
	Capital Productivity (Hours Per Year)			Real GDP / K
	(1)	(2)	(3)	(4)
Bottom Quartile	3,699	3,243	3,425	0.17
Second Quartile	4,041	3,609	3,785	0.24
Third Quartile	4,022	3,511	3,535	0.31
Top Quartile	3,861	3,282	3,296	0.53
Top/Bottom	1.04	1.01	0.96	3.12
	Electricity TFP (US = 100)			Aggregate TFP
	(1)	(2)	(3)	(4)
Bottom Quartile	96.90	87.75	88.75	36.03
Second Quartile	99.38	93.04	97.83	56.59
Third Quartile	90.43	88.42	90.14	71.61
Top Quartile	105.80	104.74	106.21	97.96
Top/Bottom	1.09	1.19	1.20	2.72
Losses	No	Yes	Yes	–
Self-Generation	No	No	Yes	–

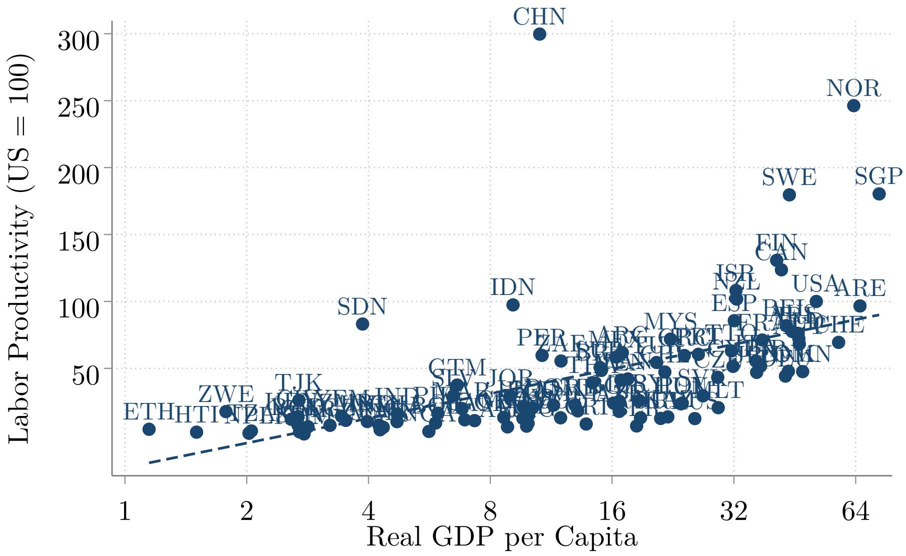
Notes: This table reports summary statistics of productivity in the electricity sectors of the countries in our data. The first panel covers labor productivity, measured in megawatt hours per worker per year. The second panel covers capital productivity, measured in hours per year. The third panel covers TFP, wher the value for the US is normalized to be 100. Column 1 reports measures that don't account for transmission & distribution losses or small-scale capital. Column 2 reports measures that adjust for transmission & distribution losses. Column 3 reports measures that adjust for both transmission & distribution losses and small-scale capital. Column 4 reports aggregate economy measures for comparison.

Figure A1: Electricity Generation Capital vs. Electricity Transmission and Distribution Capital

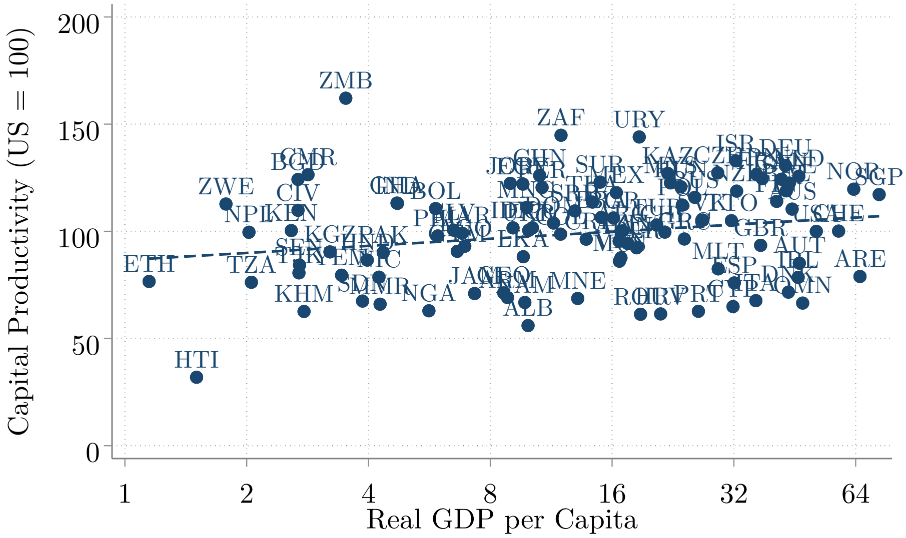


Notes: This figure reports the bivariate relationship between the capacity (in MW) of generation capital and the capacity (in MW) of transmission & distribution capital in the electricity sector. Both variables are transformed on a $\log_2$ scale. We observe a very strong relationship between the two measures of capital. In all cases countries have more transmission & distribution capacity than generation capacity. This is reasonable as electricity output is constrained by the ability to transmit and distribute what is being generated.

Figure A2: Electricity-Sector Labor and Capital Productivity Across Countries



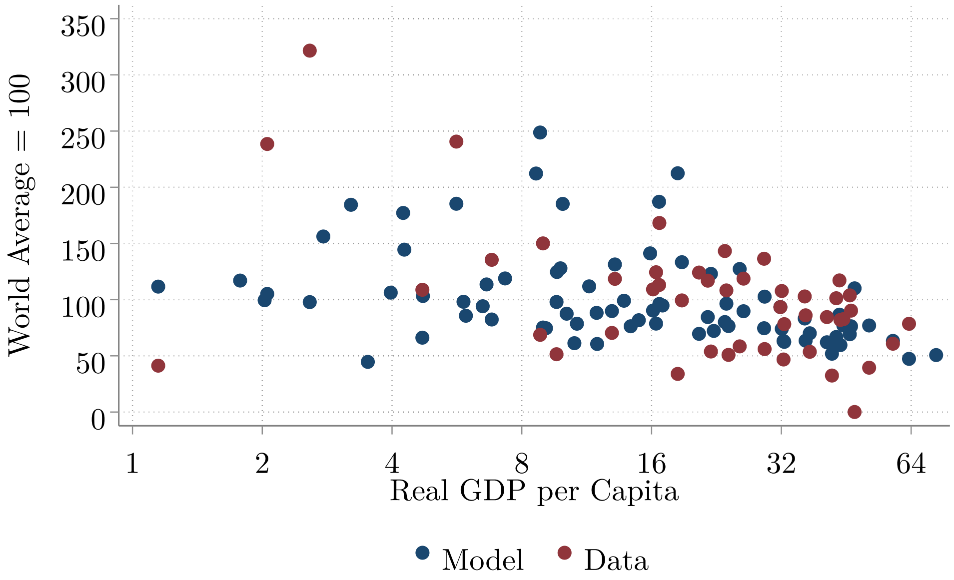
(a) Labor Productivity



(b) Capital Productivity

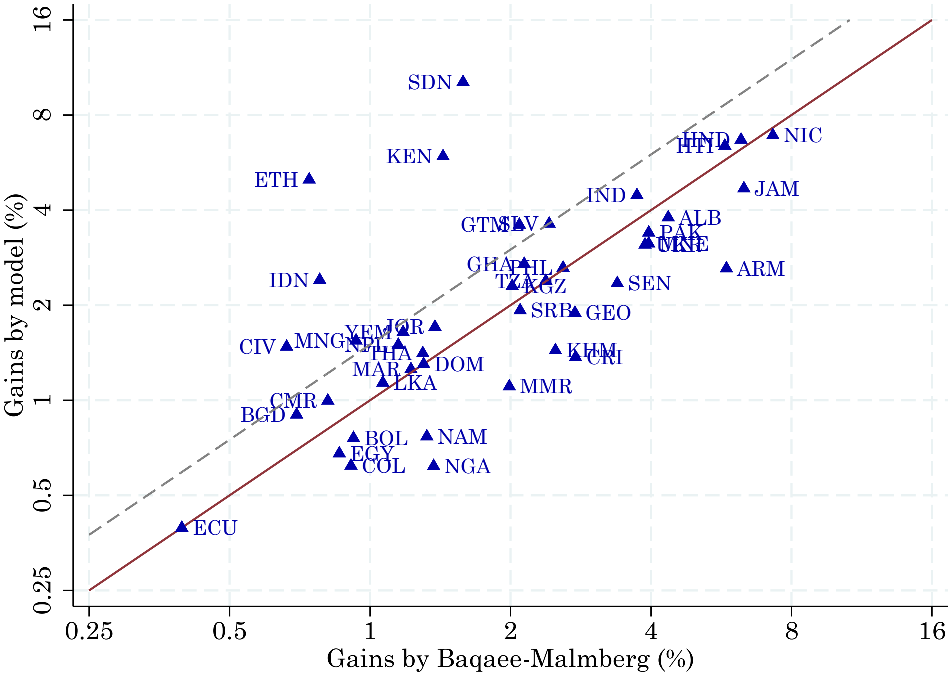
Notes: These figures document the relationship between electricity sector labor productivity and real GDP per capita (panel a) and electricity sector capital productivity and real GDP per capita (panel b). Data on real GDP per capita are taken from the Penn World Tables version 9.1. Electricity sector labor productivity and capital productivity is calculated from the data described in section 2.1. We estimate a strong negative association between electricity sector labor productivity and real GDP per capita. By contrast, we estimate a much weaker relationship between capital productivity and real GDP per capita.

Figure A3: Prices of Electricity



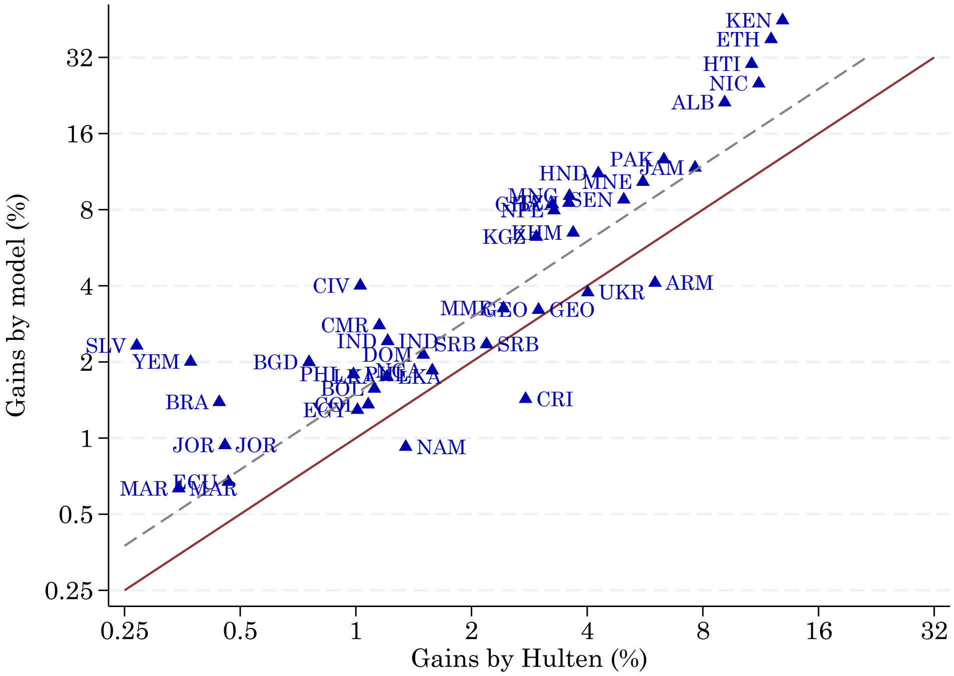
Notes: This figures shows how the models predictions for prices varies with GDP per capita. Data on real GDP per capital is taken from the Penn World Tables version 9.1. Data on electricity prices was purchased from the IEA's "Energy Prices" Database. The model's prediction is for after-tax prices.

Figure A4: Consumption Gains from Raising Electricity TFP to World Frontier



Notes: This figure plots the model's predicted long-run consumption gains from raising A_E to the world frontier in each developing country, defined to be countries in the bottom half of the world income distribution. The x-axis plots the consumption gains predicted by Baqaee and Malmberg (2025), as a frame of reference. The y-axis plots the model's predicted consumption gains. The red solid line represents $y = x$, and the black dashed line represents $y = 1.5x$, which captures the model's predictions being equal to 1.5 times those of Baqaee-Malmberg.

Figure A5: GDP Gains from Removing Distortions Starting from Counterfactually High Level



Notes: This figure plots the model's predicted long-run GDP gains from reducing all distortions starting from a counterfactually high level of distortions. The *x*-axis plots the GDP gains predicted by Hulten, as a frame of reference. The *y*-axis plots the model's predicted GDP gains. The red solid line represents $y = x$, and the black dashed line represents $y = 1.5x$, which captures the model's predictions being equal to 1.5 times those of Hulten.