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HW review 1 to 4

Ignacio J. Pérez-Arriaga
Sloan School, MITEI & CEEPR, MIT
Instituto de Investigación Tecnológica (IIT), Comillas University
Florence School of Regulation, European University Institute
Objectives for today

Discuss significant issues raised in HW 1 to 4

Provide feedback
HW1
Country selection
HW1: Countries & people

- ANGOLA, Tatiana
- BIHAR, Janak
- ETHIOPIA, Amir
- HAITI, Liam
- JHARKHAND, Payal
- KENYA, Allison
- MYANMAR, Sruthi
- NAMIBIA, Nicolas
- NEPAL, Anthony
- RWANDA, Olsen
- TANZANIA, Philip
- ZAMBIA, Lama
HW2
Cell phones & solar home systems
Question

“Cell phones and solar home systems cost about the same in sub-Saharan Africa. More people choose cell phones than electricity. Thus, is rural electrification a misallocation of resources to what people need and want?

My point here is that there are other development-enhancing services that people want and can afford and are buying, more than electricity. It calls for thought about how much different services should be provided or left to market choice; it indicates that many people have chosen cell phones but not household electricity.”
Facts

• Penetration levels in SSA (2017)
  – 44% phone (*from 25% in 2000*) & 43% electricity
    [https://www.gsma.com/mobileeconomy/sub-saharan-africa/](https://www.gsma.com/mobileeconomy/sub-saharan-africa/)

• Cell phones are cheaper than solar kits
  – See evidence in following slides
Facts


• Featured in the World Bank's 2016 World Development Report
### The cheapest countries to own a cell phone

Monthly phone usage cost in 2014 USD (not including device)

<table>
<thead>
<tr>
<th>Country</th>
<th>Monthly Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sri Lanka</td>
<td>$0.97</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>$1.42</td>
</tr>
<tr>
<td>Iran</td>
<td>$2.01</td>
</tr>
<tr>
<td>Pakistan</td>
<td>$2.12</td>
</tr>
<tr>
<td>Nepal</td>
<td>$2.49</td>
</tr>
<tr>
<td>India</td>
<td>$2.80</td>
</tr>
<tr>
<td>Bhutan</td>
<td>$2.95</td>
</tr>
<tr>
<td>Mongolia</td>
<td>$3.16</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>$3.28</td>
</tr>
<tr>
<td>Sudan</td>
<td>$3.33</td>
</tr>
</tbody>
</table>
The most expensive countries to own a cell phone
Monthly phone usage cost in 2014 USD (not including device)
The monthly cost of running a mobile phone by country
As a % of income, in USD, and in PPP terms - click columns to sort

<table>
<thead>
<tr>
<th>Country</th>
<th>% of Monthly GNI p.c (2014, ..)</th>
<th>USD (2014, Market Rates)</th>
<th>USD (PPP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congo (Dem. Rep.)</td>
<td>52.76</td>
<td>18.89</td>
<td>30.18</td>
</tr>
<tr>
<td>Central African Rep.</td>
<td>51.64</td>
<td>13.76</td>
<td>24.50</td>
</tr>
<tr>
<td>Madagascar</td>
<td>50.45</td>
<td>18.48</td>
<td>58.25</td>
</tr>
<tr>
<td>Malawi</td>
<td>48.86</td>
<td>10.98</td>
<td>40.13</td>
</tr>
<tr>
<td>Liberia</td>
<td>39.99</td>
<td>13.65</td>
<td>25.17</td>
</tr>
<tr>
<td>Niger</td>
<td>39.57</td>
<td>13.18</td>
<td>28.70</td>
</tr>
<tr>
<td>Togo</td>
<td>38.48</td>
<td>16.98</td>
<td>35.84</td>
</tr>
<tr>
<td>Burundi</td>
<td>34.72</td>
<td>7.51</td>
<td>19.39</td>
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<tr>
<td>Guinea-Bissau</td>
<td>30.04</td>
<td>14.75</td>
<td>29.59</td>
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<td>Zimbabwe</td>
<td>28.05</td>
<td>20.08</td>
<td>36.74</td>
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<tr>
<td>Mali</td>
<td>26.55</td>
<td>14.81</td>
<td>32.61</td>
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<tr>
<td>Mozambique</td>
<td>22.89</td>
<td>11.63</td>
<td>22.71</td>
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<tr>
<td>Sierra Leone</td>
<td>21.86</td>
<td>12.01</td>
<td>25.59</td>
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<tr>
<td>Benin</td>
<td>20.92</td>
<td>13.76</td>
<td>29.06</td>
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<tr>
<td>Nicaragua</td>
<td>20.54</td>
<td>17.34</td>
<td>30.95</td>
</tr>
<tr>
<td>Chad</td>
<td>20.23</td>
<td>13.60</td>
<td>22.75</td>
</tr>
<tr>
<td>Uganda</td>
<td>19.93</td>
<td>9.96</td>
<td>23.55</td>
</tr>
<tr>
<td>Comoros</td>
<td>19.45</td>
<td>13.60</td>
<td>22.75</td>
</tr>
<tr>
<td>Tajikistan</td>
<td>19.26</td>
<td>15.88</td>
<td>38.78</td>
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<tr>
<td>Senegal</td>
<td>18.94</td>
<td>16.56</td>
<td>33.73</td>
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<tr>
<td>Burkina Faso</td>
<td>18.68</td>
<td>11.66</td>
<td>25.74</td>
</tr>
<tr>
<td>Mauritania</td>
<td>16.00</td>
<td>14.12</td>
<td>35.56</td>
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<tr>
<td>Cameroon</td>
<td>15.10</td>
<td>16.22</td>
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<tr>
<td>Guinea</td>
<td>14.67</td>
<td>5.62</td>
<td>12.31</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>14.48</td>
<td>24.36</td>
<td>26.47</td>
</tr>
<tr>
<td>Haiti</td>
<td>14.06</td>
<td>9.48</td>
<td>19.06</td>
</tr>
<tr>
<td>Côte d'Ivoire</td>
<td>14.03</td>
<td>16.93</td>
<td>35.40</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>13.18</td>
<td>17.56</td>
<td>16.85</td>
</tr>
<tr>
<td>Gambia</td>
<td>12.67</td>
<td>5.27</td>
<td>19.10</td>
</tr>
<tr>
<td>Rwanda</td>
<td>11.70</td>
<td>13.71</td>
<td>15.25</td>
</tr>
<tr>
<td>Lesotho</td>
<td>10.98</td>
<td>31.38</td>
<td>35.82</td>
</tr>
<tr>
<td>Cape Verde</td>
<td>10.41</td>
<td></td>
<td>54.55</td>
</tr>
</tbody>
</table>
Facts

A store in Oshakati sells a basic solar system for N$ 12,000. This system can cater for 4-6 lights, cell-phone charging, and radio. It has a 100 W panel and a 100 Ah battery. The cheapest mobile phone that is available at MTC (a Namibian carrier) costs N$ 179. If it is bought together with a plan costing $N 169/month, including the phone, 200 mins of calls, 200 SMS and 200 MB of data per month, the overall cost of the phone after two years would be N$ 4056 (a third of the price of a solar system).

Thus, in Namibia, a basic mobile phone is significantly cheaper than a solar system. Additionally, it can be bought with no upfront payment (just the monthly fee). This makes it much easier for poor people to buy because they usually do not save up a lot of money. <Source: Nicolas Früh>
Beyond statistics

“For many consumers across Sub-Saharan Africa, the mobile phone is not just a communication device but also the primary channel to get online, as well as a vital tool to access various life-enhancing services.

Access to mobile connectivity is vital to empowering consumers and driving economic growth. The technology enhances access to many essential services, including education, health and utilities, while also enabling business models that support the efficient and sustainable delivery of key services through mobile-based platforms such as mobile money and cellular IoT.”

<Source: SSA: The mobile economy>

https://www.gsma.com/mobileeconomy/sub-saharan-africa/
Discussion

• Could funding electrification be a misallocation of resources?
  – Considerations about the value of electricity for the consumers, as compared to other goods
  – Considerations about the value of electricity access for development by itself (see discussion in HW3)
Discussion

- Considerations in support of higher comparative value of electrification access
  - It is cheaper & easier to get access to a cell phone than to electricity (connection fees); thus, more people can afford cell phones than solar kits, & affordability limitations may partly justify the higher cell phone penetration
  - A solar kit is not complete electrification, which would have much higher value (& cost) if people could purchase the appliances & pay the bill; the comparison is only valid within the range of low affordability at the bottom of the pyramid
Discussion

• (cont.)
  – Uneducated poor people may have difficulty envisioning the mid & long term electricity benefits, while phone provides communication & mobile payment immediately

• This consideration has double-edged implications. It explains why most people decide to give priority to cell phones. And it indicates that (assuming both goods are equally affordable & non compatible) this decision might be wrong
Discussion

• Considerations *questioning a high comparative value* of electrification access
  – There is evidence of the *higher level of cell phone penetration*, whose immediate interpretation is a higher consumers’ value for the cell phones
  – The most significant application of SKs (lighting) *has substitutes in kerosene & candles* (although not radio, TV, fan, etc.), while the most direct use of the cell phone cannot be replaced.
Discussion

(cont.)

– Both phones & electricity can also provide value via social status. Cell phones provide high marginal utility for mobile connectivity for businesses and social life, where the value of being connected increases if everyone else is connected.
Discussion

• Other considerations
  – It is unclear whether cell phone penetration really reaches the rural areas or the areas that do not have access to electricity.
  – There is a high likelihood that the same people with access to electricity have cell phones, and the other percentage of the population has neither.
  – Phones need charging
  – Phones can provide short-term lighting
Discussion

• Other considerations
  – Owning a mobile phone likely increases demand for electricity - the two are complimentary in the longer-term
  – The high penetration of cell phones is often largely attributed to mobile money services.
Discussion

• Some sort of takeaway
  – The higher level of penetration of cell phones does not allow to conclude that supporting rural electrification is a misallocation of resources.
  – It just happens that cell phones are purchased first.
  – As larger tiers of electrification will be reached, the value of electrification will become more important to the users. For many decades, in most countries, households have enjoyed electricity while having scarce or no phone connection (which, undoubtedly, is much more versatile & valuable now than then)
HW3
Electricity as development enabler
First, let’s review the conventional wisdom...
Development Effects of Rural Electrification

Raul Jimenez

Infrastructure and Energy Sector
Energy Division

POLICY BRIEF Nº
IDB-PB-261

January 2017
Abstract

What do we know about the effects of improved access to electricity? Does the research tell a unified story? To answer these questions, this brief examines 50 impact evaluation studies, focusing on the effects of electrification on education, labor, and income indicators. Overall, the literature finds substantial welfare gains, which tend to be greatest for women and small firms. On average, electrification leads increases of around 7% in school enrollment, 25% in employment, and 30% in incomes. However, the estimates vary widely, with many studies finding no effects, indicating weak links in the empirical literature. This review suggests that addressing the sources of such variance could be a means to fill the persistent knowledge gaps and to improve the effectiveness of electrification policies.
“For the poor, the priority is the satisfaction of such basic human needs as **jobs, food, health services, education, housing, clean water and sanitation**. Energy plays an important role in ensuring delivery of these services.”

Energy links with poverty reduction

• In modern times no country has managed to substantially reduce poverty without greatly increasing the use of energy. How? Energy…
  • boosts poor people’s productivity and thus their income
  • by powering lights and modern equipment, electricity helps improve health care and education
  • lightens women’s work
  • reduces the environmental damage from the use of traditional fuels
• The energy sector needs to work with other sectors to ensure that the poor benefit as much as possible from greater access to energy.
Energy links with poverty reduction

• Increasing income
  – Modern energy increases productivity *(lighting extends the workday)*
  – Electricity enables poor households to engage in activities that generate income

• Contributing to better health
  – Pumping and treating raw water to ensure a clean water supply
  – Boosting agricultural production reduces malnutrition
  – Switch to kerosene & LPG *(liquified petroleum gas)* to reduce harmful emissions from cooking with biomass fuels like wood & dung
(continuation)

– Refrigerate vaccines, operate medical equipment, and provide medical assistance at any time
– Dissemination of health information
– Better women literacy translates to better children health

• Supporting education
  – Access to modern energy services frees time for education
  – Boosts productivity & frees children to attend school
  – Allows study after daytime activities
  – Helps retain teachers by improving their quality of life
Table 1. Nicaragua 1998

<table>
<thead>
<tr>
<th>REGION</th>
<th>PERCENTAGE OF CHILDREN ENROLLED IN SCHOOL</th>
<th>NUMBER OF HOUSEHOLD MEMBERS WHO ARE LITERATE</th>
<th>PERCENTAGE LITERACY IN HOUSEHOLD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WITH ELECTRICITY</td>
<td>NO ELECTRICITY</td>
<td>WITH ELECTRICITY</td>
</tr>
<tr>
<td>Atlantic</td>
<td>77</td>
<td>40</td>
<td>3.02</td>
</tr>
<tr>
<td>Central</td>
<td>77</td>
<td>46</td>
<td>3.02</td>
</tr>
<tr>
<td>Pacific</td>
<td>73</td>
<td>62</td>
<td>3.79</td>
</tr>
<tr>
<td>Total</td>
<td>72</td>
<td>50</td>
<td>3.37</td>
</tr>
</tbody>
</table>

(continuation)

• Improving women’s quality of life
  – In many parts of the world women cook, collect wood and bring water
  – Modern cooking fuels save time & reduce health hazards
  – Lighting & motive power allow women to work at home & bring additional income
  – The probability that a woman will read strongly depends on having electricity at home

• Reducing environmental harm
  – Use of wood as fuel leads to forest degradation
  – Biomass combustion causes indoor pollution
  – Greenhouse emissions cause global warming
Figure 3: Household income, Electricity, and time spent reading by women, rural India, 1996

Now, let’s examine evidence that challenges the conventional wisdom
Experimental Evidence on the Economics of Rural Electrification*

Kenneth Lee, Energy Policy Institute at the University of Chicago (EPIC)
Edward Miguel, University of California, Berkeley and NBER
Catherine Wolfram, University of California, Berkeley and NBER

January 2018

ABSTRACT
We present results from an experiment that randomized the expansion of electric grid infrastructure in rural Kenya. Electricity distribution is a canonical example of a natural monopoly. Randomized price offers show that demand for electricity connections falls sharply with price. Experimental variation in the number of connections, combined with administrative cost data, reveals considerable scale economies, as hypothesized. However, consumer surplus is far less than total construction costs at all price levels. Moreover, we do not find meaningful medium-run impacts on economic, health, and educational outcomes, nor evidence of spillovers to unconnected local households. These results suggest that current efforts to increase residential electrification in rural Kenya may reduce social welfare. We discuss how leakage of funds, reduced demand (due to red tape, low reliability, and credit constraints), and other factors may impact this conclusion.

CONTENT

• The study covers 150 rural communities in Kenya, in an area where clusters of households have the opportunity of connecting to the grid at subsidized prices
• The study estimates the willingness to pay (WTP) for grid connection
• The study evaluates medium-run impacts on a range of economic, health, and educational outcomes to assess the welfare implications of mass rural electrification
Roughly 18 months after getting an electricity connection, the authors have not found meaningful medium-run impacts of electrification on economic, health and educational outcomes, nor evidence of spillovers to unconnected local households.

Consumer surplus of electrification is less than total cost of network development.

Results suggest that current efforts to increase residential electrification in rural Kenya may reduce social welfare.

DETAILS: COST / BENEFIT ANALYSIS

• The key analysis of the paper is the comparison of the electrification cost for society with the social benefit* achieved by electrification
  – How was the cost estimated?
  – How was WTP estimated?

* The paper uses the term “surplus” instead of benefit, which is confusing.

DETAILS: THE ELECTRIFICATION COSTS

• **COSTS** in the paper are just the **overnight costs of extending the low voltage grid** to reach households within 600 meters of MV/LV transformers

  – The cost of energy production is ignored, assuming that (from a societal point of view) they cancel with the payments made by consumers *(this deserves more discussion, as tariffs may not be cost reflective, & therefore the subsidies in the tariffs should enter the picture)*
The benefits to households (utility improvement) are estimated in the paper from the “willingness to pay” (WTP) of the consumers for the connection to the grid.

But for poor people, the experiment really measures the ability to pay, which is lower than the utility gain or benefit from electricity access.

Supply was unreliable, therefore reducing the WTP.

Thus, the benefits are probably substantially underestimated.


DETAILS: OTHER INFLUENTIAL FACTORS

• 18 months might be too short a period of time to observe significant impacts on some of the considered outcomes*

• The reliability of supply was poor, perhaps limiting the benefits of electrification

* In a posterior paper the authors confirm the earlier findings, now over a longer period of time.
Electrification of isolated rural communities is expensive, either by grid extension or with off-grid solutions.

– As it is children education, health services, or transportation, for these remote communities.

Does this mean that providing these expensive but essential services, whose total supply cost these communities cannot afford (remember, ability to pay is not the same as benefit or utility) or whose total supply cost exceeds the benefit to consumers, is a loss of social welfare?
(continuation)

• In most countries these **essential services** are socialized

• One thing is to accept lower service quality in remote areas & another to apply **strict cost / benefit analysis** to decide whether essential services should be provided or not

• This is why **minimum requirements** (like the Sustainable Development Goals) have been established
Goal 7: Energy Access Targets for 2030

• ... ensure universal access to **affordable**, **reliable** and **modern** energy services

• ... **increase** substantially the **share of renewable** energy in the global energy mix

• ... double the global rate of improvement in **energy efficiency**

• ... **enhance international cooperation to facilitate access to clean energy research and technology**, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology

• ... **expand infrastructure and upgrade technology** for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programs of support
• I do not think the conclusions of the study should be used to argue that grid extension is not the right approach to electrification and off-grid solutions should be adopted.
  
  – Off-grid solutions can be less expensive that grid extension in some cases, or they may be a bridge solution to a comprehensive grid extension, but this does not mean that off-grid solutions are be affordable.
Takeaways from the discussion
Electrification & social welfare

• Numerous studies have observed positive significant impacts of electrification, but some have indicated that the impact of electrification has not been as high as expected

• The results of the considered paper & other references invite to investigate
  – which conditions must accompany electrification so that development happens
  – if priority, speed, or amount in the deployment of the service – & in relation with other essential services – matters
Long-Term Impacts of Household Electrification in Rural India

Dominique van de Walle
Martin Ravallion
Vibhuti Garg
Gayatri Koolwal

The World Bank
Development Research Group
Human Development and Public Services Team
June 2013
Abstract

India’s huge expansion in rural electrification in the 1980s and 1990s offers lessons for other countries today. The paper examines the long-term effects of household electrification on consumption, labor supply, and schooling in rural India over 1982–99. It finds that household electrification brought significant gains to consumption and earnings, the latter through changes in market labor supply. It finds positive effects on schooling for girls but not for boys. External effects are also evident, whereby households without electricity benefit from village electrification. Wage rates were unaffected. Methodologically, the results suggest sizeable upward biases in past estimates of the gains from electrification associated with how past analyses dealt with geographic effects.

This paper is a product of the Human Development and Public Services Team, Development Research Group. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at dvandewalle@worldbank.org.
Energy is necessary, but not sufficient, for development

• Without ensuring minimum access to energy services for a broad segment of the population, countries have not been able to move beyond a subsistence economy.

• But merely introducing cheap, easily available modern energy is not enough to ensure socioeconomic progress. Other factors are also crucial.

  – transportation to enable exchange of goods & services, communication, water supply, health & sanitation, education, adequate housing, political rights
The role of energy in the SDGs

• There seems to be a consensus that **sustainable energy is needed in the implementation of almost all the other goals** in the agenda, from eradicating poverty to fighting climate change.

• Thus, **the impact of electrification extends in many directions** & it is difficult to quantify, particularly in the long term.
Energy links with poverty reduction

• Clearly energy for the sake of energy is not useful. Its utility lies in facilitating human development.

• The energy sector has strong links with poverty reduction through income, health, education, gender, and the environment.

• These links suggest that in a comprehensive approach to development, the energy sector has to be associated with other sectors to ensure that the poor benefit as much as possible from greater access to energy supplies.
And to finish…

• Access is a key enabling factor, necessary but not sufficient
• Perfect access is the one that does not constrain energy utilization, but it does not guarantee development
• Economic development will happen if other factors coincide and if productive factors exist & developers nudge / facilitate their adoption
HW4

On the several electrification modes
Question 2: On the diverse electrification modes

• Based only on techno-economic arguments (i.e., avoid as much as possible to include here social, cultural, political or environmental considerations), present some reasons (three is a reasonable number) that can justify supplying non-electrified households and other buildings, in the system that you have selected, with off-grid solutions (i.e. mini-grids and standalone systems) and conversely (i.e. reasons in favor of using grid extension for electrification).

• Same question, but now include other considerations: social, political, environmental or other.
Only techno-economic reasons

PRO OFF-GRID SOLUTIONS

• The min cost solution is a mix of the three delivery modes.
  – For a given demand, off-grid is less expensive than grid extension beyond some combination of cost of generation, distance to the grid, dispersion of demand, and low individual and collective demand that can justify the grid connection investment (this includes incurring in the cost of a MV/LV transformer, which may be too large and expensive for isolated loads or load aggregations that are still too low).

• Poor reliability of the main grid.

• (against) Anticipated future large demand growth (this is particularly important for the network, which is lumpier than PV or demand)
Other factors

PRO OFF-GRID SOLUTIONS

• Tariffs are so low that distros do not want to connect more customers. This leaves space for off-grid electrification, even if not profitable (viability gap covered with public funds or donors).

• Distros are in bankruptcy and do not have investment capacity. Same as in previous point.

• Anchor loads (or some special cases, where productive uses of electricity improve the economic viability of the project) make the mini-grid to be profitable.

• Cherry picking of PAYG companies, or similar. No guarantee that nobody will be left behind.
Questions or comments?