Electrification, Environment, and Economic Development in Developing Countries

PhD Defense

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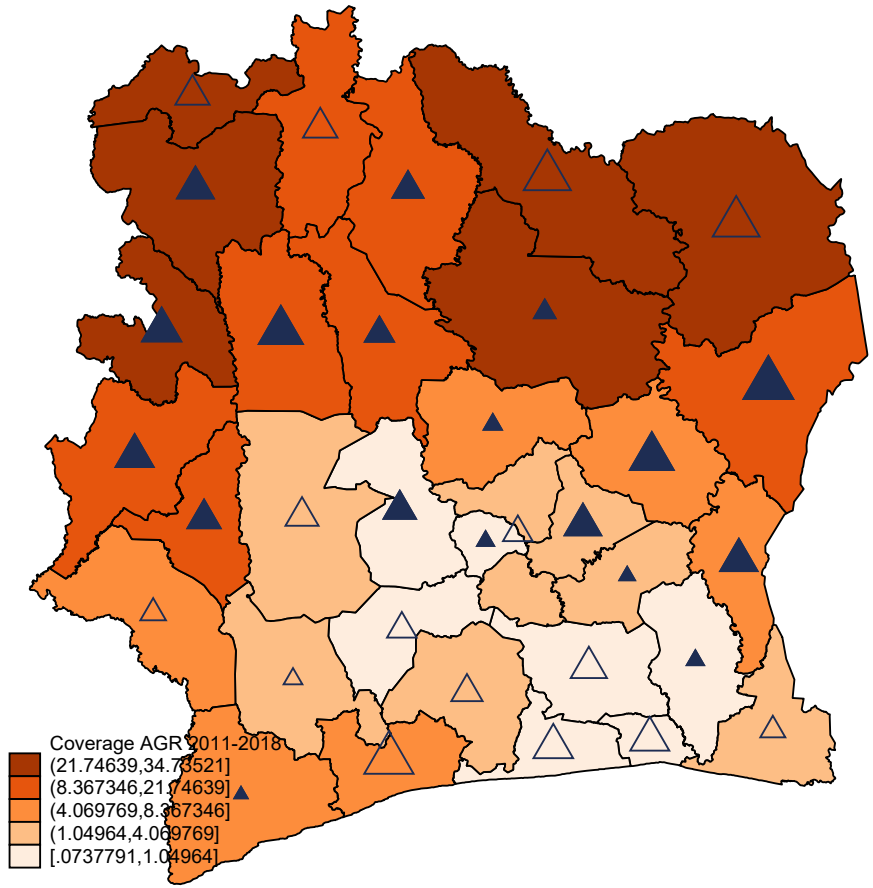
Motivation

- **Reliable electricity** $\Rightarrow$ economic growth, poverty reduction, improved quality of life:
  - It can increase firms' productivity, reduce production costs and increase the producer's surplus and income (Rud, 2012; Fisher-Vanden et al., 2015; Allcott et al., 2016).
  - It accelerates **structural transformation** (Rud, 2012) and enhances **economic development** (Ferguson et al., 2000; Wolde-Rufael, 2006).
- However, **electrification programs** raises concerns about their **potential environmental impact** (Villoria et al., 2014).



Solid triangles indicate values over the mean of Forest loss AGR 2011-2018.
Source: MPEER, Hansen et al, 2013

Motivation

- We explore the links between electrification, deforestation, and economic development.
- The primary goal is to offer valuable insights into the impacts of electrification on both **environmental sustainability** and **economic development** in the context of ongoing electrification efforts.
- The findings presented in this thesis could guide decision-makers in crafting policies that promote a harmonious balance between **economic development** and **environmental conservation**.

Outline

1. Chap I – Access to electricity and household practices potentially contributing to forest loss in Côte d'Ivoire
2. Chap II – Electrification and Deforestation in Côte d'Ivoire: a spatial econometric analysis
3. Chap III – Power Sector Regulation and Private Investment in Power Generation: Evidence from Africa
4. Chap IV – Power Constraints and Firm-level Total Factor Productivity in developing countries

Outline

Background

- From **16 million ha** of forest in the 1960s, the country now has only about **2.5 million ha**.
- **Cocoa plantations** as source of a loss of **200,000 ha/yr** (SODEFOR). Agricultural sector $\Rightarrow$ **62%** of the forest loss (REDD+, 2018).
- Around **2.4 million tons** of firewood are consumed annually for cooking and heating (IEA, 2021). Biomass $\Rightarrow$ **80%** of the country's total energy consumption.
- Ivorian government initiated an extensive electrification program (Axis III of the Ps-Gouv).
- The program has 3 components: PRONER, PEPT, and 20% reduction in the social tariff.
- Installed capacity increased from **1,391 MW** in 2011 to **2,230 MW** in early 2022. **6949 localities** (over 8518) electrified, and the coverage rate raises from **33%** to **82%**.

Chapter I

- Electrification reduces the need both to expand farms and to collect firewood, and is therefore an **effective way to mitigate deforestation** (An et al., 2002; Dube et al., 2014; Mensah and Adu, 2015; Tanner and Johnston, 2017; Bakehe and Hassan, 2022).
- Nevertheless, the extension of the electricity network (migration) or the improvement in agricultural profitability (cash crop) generated by electrification could be a **source of deforestation** (Geist and Lambin, 2002; Villoria et al., 2014).

Research question

1. What is the relationship between electricity access and biomass fuel consumption in Côte d'Ivoire?
2. How does electricity access influence the size and expansion of arable farms?

Data

- Last four waves of the Households LSMS (1998, 2002, 2008 and 2015) in the country, **nationally representative**.

Methodology

- We adapt Angelsen (1999)'s **theoretical framework and explore a potential link** between electrification and arable land expansion from a theoretical point of view.
- **Cohort fixed effects** as our main specification **to capture the unobservables factors as long as they are fixed over time**.
- Robustness check to **several alternative specifications** when observing households instead of cohorts of households (probit, matching, weighting).

We highlight:

Main results

- Robust evidence that the **electrification significantly reduces both arable farms size and biomass fuel consumption** (firewood collection).
- We also document that the **effect is driven by the rural areas**.
- We provide evidence on a **threshold effect of 80%**.

Outline

Background

- **Same forest loss overview and electrification effort** in Cote d'Ivoire as pointed out in Chap I.
- Previous analysis on the issue are **micro** or **macro**. We propose an intermediate level of scale between micro and macro (**meso**).
- Mensah and Adu (2015) focus on the decrease in the use of wood for cooking due to electrification in Ghana.
- Tanner and Johnston (2017) on a panel of 158 countries for the years 1990, 2000 and 2010. They show that access to electricity in rural areas reduces deforestation rates.

Research question

1. To what extent does improved electricity access influence overall deforestation in Côte d'Ivoire?
2. Does the spatial scale matter?

Data

- **Deforestation**: Forest cover loss event available at regional and departmental scale (Hansen et al., 2013).
- **Electrification**: Evolution of the coverage rate available at the regional scale only (MPEER). Night lights intensity data available at regional and departmental scale (NOAA National Geophysical Data Center).
- **Controls**: Precipitation and Temperature (University of Delaware); Population density (Warszawski et al., 2017); Gross Domestic Product in millions of dollars (Ghosh et al., 2010); Percent forest cover (Hansen et al., 2013); ACLED Conflict Events (Raleigh et al., 2010); Travel time to major cities (Nelson, 2008).

Methodology

- Exploratory spatial data analysis and Choice of the best spatial specification.
- Random effects model with a SAR process.
- As highlighted in this literature (see Baggio and de Barros, 2021; Robalino and Pfaff, 2012), the **analysis of the deforestation phenomenon requires the consideration of spatial interactions between different localities**.

We highlight:

Main results

- The **concordance** of the night lights intensity data with the official data.
- The existence of **spatial interaction depends on the chosen spatial scale**.
- That after considering the optimal spatial scale and taking into account both spatial effects and unobservable individual and temporal effects, our empirical results suggest that **electrification increases overall deforestation in Cote d'Ivoire** contrary to Tanner and Johnston (2017).

Outline

Background

- **Weak access to electricity in Africa due mainly to the lack of adequate public investment in the sector:**
  - Access to electricity in Africa in 2020 is estimated at **54%** (IEA).
  - Nearly **600 million Africans** still do not have access to electricity.
  - Severe economic and fiscal constraints (ERI 2020).
- **Opening up of power generation to private actors in order to provide the capital needed to meet the challenges (IPPs/PPPs):**
  - But private actors also face major challenges: **local capital markets are weak and limited** (debts essentially denominated in foreign currencies) and **inputs are mostly imported**.
  - Currency depreciation leads to an **increase in the debt burden for private actors and the cost of imported inputs**.

- **Favourable role** (Pargal, 2003; Wallsten, 2002; Rubino and Cuomo, 2015); in **developing countries** (Andres et al., 2007; Cubbin and Stern, 2005; Gassner et al., 2009), and in **electricity sector** (Bergara et al., 1998; Zhang et al., 2008; Cubbin and Stern, 2006).
- **IRA do not guarantee an improvement in private investment** due to **political interference** or **not adapted measures** (Parker and Kirkpatrick, 2012; Bertoméu-Sánchez et al., 2018; Andrés et al., 2013; Carvalho et al., 2012; Estache et al., 2010).

Research question

1. How do currency and inflation crises potentially impact power generation in Africa?
2. To what extent does the presence of an IRA, an automatic tariff adjustment mechanism, and the cost reflectivity help mitigate challenges within the power generation sector?
3. How do various regulatory strategies compare in their efficacy to mitigate the negative effect of crises on private investments in the power generation industry?

Data

- Data collection from official sources, ERI, and U.S. Energy Information Administration (EIA). We consider a panel of 54 African countries over the period 1990-2019.

Methodology

- Theoretical framework based on Nucci and Pozzolo (2001): **lack of integration of inter-country power networks**, and **need for actions**.
- **Local projections** combined with a '**doubly robust**' estimator, AIPW (Jordà, 2005; Lunceford and Davidian, 2004; Jordà and Taylor, 2016).
- Robustness using De Chaisemartin and d'Haultfoeuille (2022) DID estimator.

We highlight:

Main results

- Inflation and currency crises **(-) affect** private participation in power sector investment.
- These (-) **effects are mitigated for the countries that have established an IRA** compared to countries without.
- **Cost reflexivity would be much more effective**, followed by the automatic tariff adjustment mechanism, compared to a IRA.

Outline

Background

- Better power infrastructure $\Rightarrow$ economics growth and development outcomes.
- But in developing countries firms faced difficulties to connect to the grid / frequent outages.
- For 45.9% of firms in AFR and 41.2% in SAR, power is a major or severe constraint.
- **Negative effect** (Fisher-Vanden et al., 2015; Allcott et al., 2016; Cole et al., 2018; Elliott et al., 2021; Hardy and McCasland, 2021; Abeberese et al., 2021), **Significant but weak effect** (Grainger and Zhang, 2017), **No significant effect** (Scott et al., 2014).

Research question

1. How do power constraints influence the productivity of manufacturing firms in DC?
2. How does the impact of power constraints on firms' productivity vary based on their severity?
3. What are the potential pathways through which power constraints affect firms' productivity?
4. How do the effects vary across different levels of economic development and geographical regions?

Data

- The World Bank Enterprise Surveys (**31,406 manufacturing firms in 84 developing countries** from 2006 to 2019).

Methodology

- Theoretical framework based on that of Hsieh and Klenow (2009) and Xiao et al. (2022).
- The effect is either **negative**, **positive**, or **indefinite** following the value of the **elasticity of substitution**.
- The infinite limit of the effect **converges toward zero**.
- Empirical approach: to **compensate for the limits linked to the Hydro-IV** (as in Fisher-Vanden et al., 2015; Allcott et al., 2016; Cole et al., 2018; Elliott et al., 2021), we use a weighting-based approach (**Entropy Balancing**, Hainmueller, 2012) + large set of robustness checks (without weighting, clustered by industry, alternative outcome, placebo test, etc.).

We highlight:

Main results

- A **(-) effect** of outages on TFPR and a strong **link between the severity of self-reported power constraints** by firms and the magnitude of productivity loss.
- The **(-) effect found in LIC far exceeds those found in MIC**. **Significant effect** only for the **LIC** (≈SSA) and for the **Upper MIC** (≈MENA).
- Transmission channels: **capacity utilization** and **losses in % of sales.**
- Mitigating factors: **back-up generator reduces the negative effect by half** and **R&D mitigates the negative effects.**

Concluding remarks & Policy recommendations

Chapter I & Chapter II:

- Promote **alternative energy access policies** to reduce huge subsidies (e.g. mobile money roll out).
- **Locality-level analysis** to address the potential issue of intra-country heterogeneity highlighted by Tanner and Johnston (2017).
- Partial **favorable** effects Vs Overall **unfavorable** effects**.**

Chapter III & Chapter IV:

- Promote **local production of equipment**, **domestic capital mobilization**, and more **renewable energy sources**.
- **Back-up generator reduces the negative effect of power constraints by half**, but do not fully correct the shocks.
- **Set up IRA** + **tariff** (tariff adjustment, cost reflectivity, etc.) and **non-tariff** measures (master plan) + **Open up generation to private actors** (through IPPs, PPPs, etc.) + **Improved institutions to attract FDI** $\Rightarrow$ virtuous circle for the economy.

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