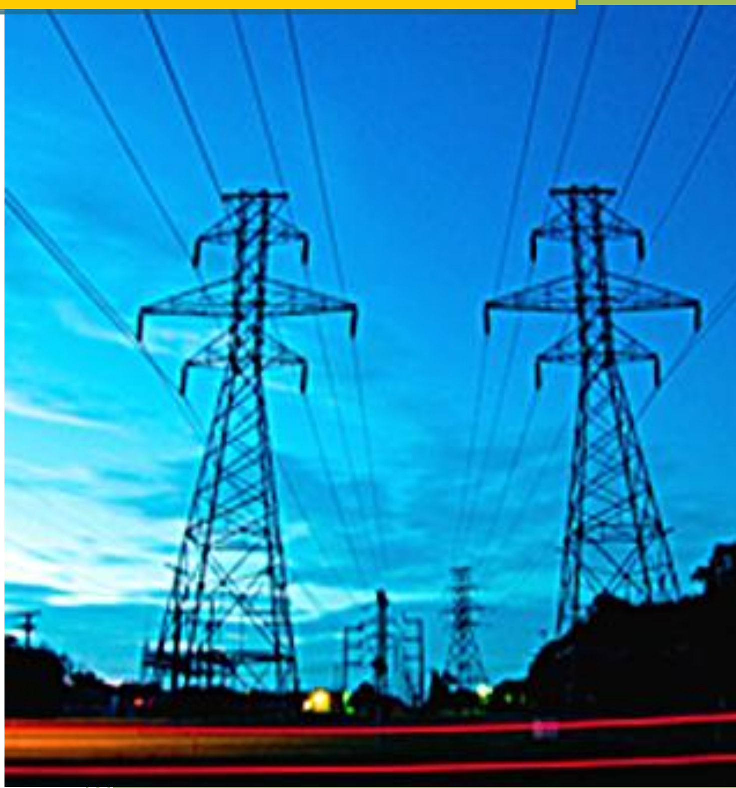
REVISITING POLICY OPTIONS ON THE MARKET STRUCTURE IN THE POWER SECTOR



The Energy Sector Management Assistance Program

PUBLIC-PRIVATE INFRASTRUCTURE ADVISORY FACILITY

Acknowledgments

The report was developed by a team led by Maria Vagliasindi, Lead Economist and John Besant Jones, Lead Energy Adviser, Energy Anchor, with input from Pedro Antmann, Senior Energy Specialist Federico Goni, ETC, FEU, Vera Kehayova, STC, Energy Anchor and Evgenia Shumilkina, ETC, Energy Anchor. Ashaya Basnyat, JPA, Energy Anchor and Wang Ying, Wang, Consultant, Energy Anchor provided some research support. The Report has been partially funded by ESMAP and PPIAF, whose financial support and partnership are gratefully acknowledged.

We are most grateful to Aberdare Engineering Limited (Kenya, Uganda and Tanzania) Enrique Crousillat and Enrique Tucto Lavado (Peru), Carlos Romero (Argentina) Mohamed Salah Elsobky (Egypt), Tuan Anh Nguyen (Vietnam), Mercados de Energia Consultoria Ltd (Brazil) and PA Consulting Group (Argentina, Barbados, Brazil, Chile and Peru) for collecting data through detailed survey and interview with local stakeholders and producing background reports for selected countries indicated in parenthesis.

The report would not have been possible without the invaluable advice, comments, and suggestions of the Expert Advisory, including Emmanuelle Auriol, Professor of Economics, University of Toulouse, France, John Besant-Jones, Lead Energy Adviser, World Bank, Pasquale Cirillo, Lecturer and Fellow in Econometrics and Risk Analysis, Institute of Mathematical Statistics, University of Bern, Switzerland, Istvan Dobozi, Lead Energy Economist, ESMAP, Antonio Estache, Jose Luis Guasch, Paul Grout, Professor of Political Economy, Department of Economics & Centre for Market and Public Organisation, University of Bristol & OFGEM Advisor, UK and Clive Harris, and Jaime Millan, former Principal Energy Economist, Infrastructure and Financial Markets, Sustainable Development Department, IADB. The main results of the Report and the individual case studies have been presented to a number of internal and external learning events, including Energy Week 2011 which was held in March 14-16 and a half a day workshop which was held on June, 9, 2011.

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Executive Summary

Study Objectives and Background

The objectives of this study are threefold:

- ***To develop a taxonomy of the existing power market structures***, as shown by the extent of vertical and horizontal unbundling found among restructured power systems, across developing countries;
- ***To design an analytical framework for assessing the desirability of unbundling under the variety of economic conditions found among developing countries***;
- ***To propose insights for operational guidance on alternative market structures based on relevant criteria***, in particular on the initial conditions of a country and its power sector.

Unbundling is not an end itself, but rather a means to achieve better performance. Accordingly, the key objective of the analytical framework is to explore the links between alternative market structures and performance (in terms of access, price, quality, technical and financial performance). The results are crucial for providing policy advice, by offering alternative options to policy makers based on the lessons learned from the taxonomy of different market structures, tailored to different national peculiarities.

The study specifically examines whether power system size and country per capita income can be reliable indicators of initial conditions for guiding policy on power market structure. This guidance is needed to address issues such as whether there are solid foundations for recommending vertical unbundling for small power systems in low-income countries, particularly in the absence of short term privatization prospects. The proposed policy recommendations therefore have to be tailored to the specific taxonomy of market structures that characterize the electricity sector in developing countries.

The existing variety of power supply structures reflects differing views and a degree of theoretical ambiguity in the economic literature on the effectiveness of unbundling and competition in network industries on issues such as gains from competition versus economies of co-ordination in vertically integrated systems. In practice, the benefits of each reform and restructuring must more than compensate for the increase in transaction costs of unbundling vertically integrated systems.

Reform to date, though, is unevenly spread among regions. Countries in Latin America and the Caribbean and in Europe and Central Asia account for all the countries that have progressed to the two most advanced stages described above. In Africa, South Asia and the Middle East, progress to date is generally limited to the first two stages with long-term contracts by IPPs to supply incumbent utilities. Some countries in East Asia, for example, have made tentative steps to further their reforms.

The current distribution of power markets around intermediate structures between full integration and full unbundling suggests that there has not been a linear path to reform in practice. Instead, many developing countries may retain intermediate structures for foreseeable future. This possibility exposes a large gap in understanding about power market structures, since most theoretical work has focused on the two extreme structures and there is limited evidence on the impact of unbundling for developing countries.

The study reports the evidence from econometric analysis and case studies on the (relative) success of achieving the objectives of unbundling. These objectives may be to enhance transparency and governance, attract private sector investment, and/or to create a competitive market and ultimately its impact on performance. In some cases restructuring had the purpose of creating an enabling environment to attract private sector investment taking some level of market risks and/or commitments to efficiency improvements. Transferring to the private investor market risks requires greater transparency and predictability, which may be more difficult to obtain in a sector with an integrated monopoly power utility to which for example the private generator is obliged to sell.

Study Analytical Framework and Approach

The approach adopted for this study is twofold: to map the existing approach to vertical and horizontal unbundling of power sectors adopted by developing countries, and to undertake econometric analysis and detailed case studies to better understand and assess the desirability of unbundling the sector under developing country conditions.

The study applies the "ceteris paribus" approach, while recognizing the potential influence of additional issues pertaining to the broader set of reforms in the power sector. As the form and extent of unbundling determines the market structure, particular attention is devoted to the analysis of key decisions through the lens "structure/ownership" vis-à-vis "contracts/market rules". Namely, the analysis separates within each market structure the key decisions that have been "internalized" within the firm through the existing "structure/ownership" from the ones that have been delegated to outside "contracts/market rules", depending on the transaction costs involved.

The study proposes an analytical approach to model market structure**,** together with ownership and regulation, controlling for several variables, as determinants of performance across several indicators of performance, including access, operational and financial performance and environmental sustainability. The study uses the following indicators of power sector performance indicators for this regression analysis:

- **Access -** Residential access to electricity (% population)
- **Operational Efficiency -** Energy sold per employee (MWh per Employee)
- **Financial Efficiency -** Tariff level (US$c per KWh)
- **Environmental Sustainability -** Carbon Emission Index (CO_2 ton/KWh)

This methodology adopts a novel approach to specifying variables with respect to most empirical studies. To date, there has been limited empirical work including market structure variables in the analysis, particularly in the case of developing countries. Only a selected number of variables of performance have been used in the literature and there is no evidence reported on the impact of reforms in terms of environmental sustainability. The study uses the following main explanatory variables that influence power sector performance for this analysis:

- **Degree of vertical unbundling**: partial vertical unbundling or full vertical unbundling: = 1 from the year of separation of generation from transmission and distribution; = 0 otherwise.

- **Degree of Disaggregation**: the reverse of the Hirschman-Herfindal index (HHI), computed separately for the generation, transmission, and distribution segments; in the case of generation is expressed in installed generating capacity (MW); in the case of transmission expressed in terms of km line length without discrimination between transmission voltage levels; in the case of distribution expressed in terms of total retail sales (MWh)
- **Share of Private Sector Participation**: the percentage of private sector participation expressed in installed generating capacity (MW) in the generation segment; expressed in terms of km line length in the transmission segment; and expressed in terms of total retail sales (MWh) in the distribution segment
- **Introduction of a regulatory agency**: = 1 from the year of establishment of a regulatory agency; = 0 otherwise.

The study uses GDP per capita and installed capacity as control variables. As it is a priori difficult to make assumptions about the explanatory power of the selected independent variables including various indicators of unbundling and other sector reforms on the dependent variables, the study runs the specifications of the model using both Fixed Effects and Random Effects regressions.

The data set is based on a panel of 22 countries for a period beginning in 1989 and extending through 2009. The maximum total number of maximum observations is 440. The selected countries and their power sectors are summarised in the following paragraphs.

A series of country case studies is also carried out to support the analytical approach described above. The selected countries cover all six developing country regions, and thereby reflect broad regional features such as Africa's low access rates and underdeveloped transmission networks; Europe and Central Asia's (ECA) full access rates, highly developed transmission interconnections, historically surplus generating capacity, and the strong influence from the EU and Russia; Latin America and the Caribbean's (LAC) leadership in market reform and large amounts of hydropower capacity; East Asia's and South Asia's high growth in power demand and therefore need for generation capacity; and Middle east and North Africa's (MENA) emergence as a strategic crossroads in energy trade.

The case studies are predicated on the hypothesis that power system size and per capita income appear to influence the choice of power market structure in developing countries. A clear empirical threshold for unbundling power systems currently appears to separate developing countries into groups which is defined in terms of power system size of 1000 MW and country annual per capita income of $900. The majority of developing countries with unbundled power systems lies above both of these thresholds. On the other hand, the majority of developing countries with vertically integrated power systems lie below both of these thresholds.

The performance of countries with unbundled power sectors is compared to the counterfactual of countries that have a vertically integrated structure. This comparison is undertaken within each group of countries determined by the threshold levels of system size and country annual per capita income. The four groups of countries are referred to as Groups A to D. Group A consists of countries in which both power system size and per capita income are above the threshold levels, Groups B and C are the ones for which either power system size or per capita income is below one of the threshold level and Group D is the one for which both power system size and per capita income are both below the threshold levels.

The case studies proposed for each of the groups are as follows, as indicated in Table A.

Table A
Sample Selection for Econometric and Case Studies Analysis

Country Group	Region
Group A (large system size and high GDP per capita)	
Chile Argentina Peru Brazil	Latin America and the Caribbean
Turkey Czech Republic	Europe and Central Asia
Egypt	Middle East & North Africa
Indonesia Korea	East Asia and the Pacific
South Africa	Sub-Saharan Africa
Groups B & C (intermediate cases)	
Jordan (↑ Group A)	Middle East & North Africa
Vietnam (↑ Group A)	East Asia and the Pacific
Indian State of Gujarat (↑ Group A)	South Asia
Indian State of Andhra Pradesh	
Indian State of West Bengal	
Barbados	Latin America and the Caribbean
Botswana Zambia	Sub-Saharan Africa
Cyprus	Europe and Central Asia
Group D (small system size and low GDP per capita)	
Kenya (↑ B)	Sub-Saharan Africa
Tanzania	
Uganda	

Note: the entries in red refer to countries that moved from one group to another during the data period.

- **Group A:** The following ten countries have been selected for this group: **Argentina, Brazil, Chile, Czech Republic, Egypt, Indonesia, Korea, Peru, South Africa, and Turkey**. The performance of Czech Republic, Egypt, Korea, Indonesia and South Africa (all of which display either a vertically integrated structure or in the case of Czech Republic and Egypt, simply legal unbundling, under a holding structure in the case of Egypt) are compared with Argentina, Brazil, Chile, Peru and Turkey that, instead, have moved reforms forward by introducing a competitive wholesale market.

❖ **Group B and C:** The performance of countries that have kept a vertically integrated structure, including **Barbados**, **Botswana, Cyprus and Zambia** is compared with **Vietnam,** some of the **Indian** power sector regional structures (**Andhra Pradesh, Gujarat and West Bengal**) that went further in the process of unbundling and **Jordan** which unbundled its power sector and privatized most of it.

❖ **Group D: Kenya**, and **Tanzania** are compared against **Uganda**, the only Sub-Saharan African country where a single buyer model has been introduced. **Tanzania** undertook a management contract from 2002 to 2006. Overall vertical integration in the sector has not changed much in **Kenya**, with transmission and distribution now bundled and generation unbundled into a few suppliers where the proportion of total installed generating capacity under private ownership increased from 16% in 2001 to 46% in 2007.

Conclusions

The results of the analysis carried out for this study confirm the following conclusions for policy guidance on power market restructuring for developing countries:

- ***Unbundling deliver results in terms of*** several performance indicators when used as an entry point to implement broader reforms, particularly introducing a sound regulatory framework, reducing the degree of concentration of the generation and distribution segments of the market by attracting additional number of both public and private players and attract private sector participation.
- ***There seems to be credible empirical basis for selecting a threshold power system size and per capita income level*** below which unbundling of the power supply chain is not expected to be worthwhile.

Partial forms of vertical unbundling do not appear to drive improvements, probably because the owner was able to continue exercising control over the affairs of the sector and hinder the development of competitive pressure within the power market.

The analysis with the regression model used for the study produces the following main findings.

A. Vertical unbundling:

❖ The level of access is positively linked to full vertical unbundling, even if not significantly so. Partial unbundling is negatively and significantly associated with lower levels of access.

❖ The level of labor productivity (expressed in terms of energy sold per employee) is significantly reduced by both partial and full vertical unbundling.

❖ Full unbundling significantly enhanced the level of tariffs, whereas partial unbundling has no significant impact on tariffs.

❖ Partial and vertical unbundling is associated with higher carbon emissions, but only partial unbundling significantly so.

Differential impact of vertical unbundling in Groups A and D

- ❖ Vertical unbundling (in both specifications, namely either partial or full or full only) when interacted with Group A is significantly associated with enhanced access and more sustainable levels of CO2 emission generated by fossil fuels, reflecting both economic and environmental benefits to power users, due to increased efficiency of use of fossil fuels. The opposite result holds for Group D.
- ❖ There is no significant link between vertical unbundling and enhanced operational or financial efficiency for Group A, whereas there is a positive and significant link for Group D. This implies that for Group A the high prevailing level of labour productivity offers decreasing returns to scale, or there is an increasing use of outsourcing. For group D the benefits of unbundling may be reflected mainly through restructuring and laying off of redundant employees.

B. Degree of disaggregation:

- ❖ The level of access is positively and significantly linked to the increase of disaggregation in generation. This result can be interpreted noting that developing countries have been able to scale up access after attracting more players and investment in generation.
- ❖ Labour productivity is enhanced by the increase of disaggregation in distribution. More players in distribution are expected to drive efficiency gains through means such as benchmark competition.
- ❖ More disaggregation in distribution drives electricity tariffs down, most likely as a result of benchmark competition and less collusion between players in the market.
- ❖ Higher competition in generation is significantly associated with higher sustainable environmental outcomes, reducing the carbon emissions from fossil fuels.

Differential impact of disaggregation in Groups A and D

- ❖ Higher disaggregation of the generation segment of the market when interacted with group A is significantly associated with enhanced access and more sustainable levels of CO2 emission generated by fossil fuels, reflecting the benefits to the users as well as to environment, due to increase efficiency of use of fossil fuels when more players are introduced. For Group D a trade off emerges between reduced access, but a more sustainable level of CO2 emission generated by fossil fuels.
- ❖ Reduction in the concentration of the distribution segment of the market for the countries belonging to Group A is positively and significant linked with enhanced operational efficiency, but there are no links with enhanced financial efficiency. This implies that for group of countries the already achieved in the level of tariff is already so high that there are decreasing returns to scale. Reduction in the concentration of the distribution segment of the market for the countries belonging to Group D is negatively linked with operational and financial efficiency, but not significantly so.

C. Regulation:

- The introduction of an autonomous regulator is significantly positively associated with higher access, confirming that regulators can also play an important role in ensuring that contracts were effectively designed.
- The presence of autonomous regulator has also significantly contributed to higher labor productivity, most likely by creating a more even playing field to attract private participation in distribution.
- The presence of an autonomous regulator is also significantly and positively associated with higher tariffs, reflecting the need to insulate crucial decisions related to pricing from political interferences.
- The presence of an autonomous regulator is also significantly associated with higher carbon emissions, proving that environmental considerations have a relatively lower priority compared to the traditional functions of energy policy and regulation, such as to protect consumers from high prices and ensure that power firms will be able to recoup their investment. These goals can be sometimes conflicting with each others.

Differential impact of regulation in Groups A and D

- The introduction of an autonomous regulator when interacted with Group A is significantly associated with enhanced access, higher operational efficiency, lower tariffs and more sustainable level of CO2 emission generated by fossil fuels, reflecting the benefits to the users, producers as well as to environment, due to increase efficiency of use of fossil fuels. In contrast, the introduction of an autonomous regulator when interacted with Group D is significantly associated with reduced access, lower operational efficiency, higher tariffs, reflecting a lack of benefits to users and producers. It is however associated with more sustainable level of CO2 emission generated from fossil fuels, as well as to environment. This result underscores the challenges in implementing regulatory reforms in this group of countries.

D. Private Sector Participation:

- The introduction of private sector participation in generation also is significantly linked to access expansions, proving that IPPs and divestiture of formerly state-owned generators can deliver positive results. The introduction of private sector participation also helped to significantly enhance operational efficiency and labor productivity in distribution.
- A higher share of private sector participation significantly raises the level of tariffs, most likely reflecting the need to raise tariffs to attract private participation in distribution.
- Private ownership in generation is also significantly and positively associated with less environmental sustainable outcomes, raising the carbon emissions from burning fossil fuels.

Differential impact of private sector participation in Groups A and D

- The introduction of private sector participation in the generation segment of the market when interacted with Group A is not significantly associated with access or carbon emissions generated from fossil fuels. This implies that for countries belonging to Group A, the achieved level of access is already so high that privatization of generation is not sought to enhance connectivity. There is also no significant evidence of environmental unsustainability results brought by the private sector in generation. The introduction of private sector participation in the generation segment of the market when interacted with Group D is significantly associated with reduced level of access but is not significantly linked to the carbon emission generated by fossil fuels.

- The introduction of private sector participation in the distribution segment of the market for the countries belonging to Group A is positively and significant linked with enhanced operational efficiency, but there are no links with enhanced financial efficiency. In the case of financial efficiency, instead, the overall link between private sector participation in distribution and tariff was positive and significant, reflecting the fact that in order to attract the private sector more cost reflective tariffs were needed. This seems to imply that for Group A of countries the already achieved level of tariff is already found enough to attract private sector participation in distribution. The introduction of private sector participation in the distribution segment of the market for the countries belonging to Group D is negatively and significantly linked with operational efficiency, but there are no links with enhanced financial efficiency.

E. Control variables:

- As expected, countries characterized either by higher income countries or larger system size are characterized by significantly higher levels of access, labour productivity and tariffs. The links with environmentally sustainable outcomes are instead different. Ceteris paribus, as one would expect, higher income countries are positively associated to higher carbon emissions, whereas countries characterized by larger system size are negatively and significantly associated to lower carbon emissions. The latter result is most likely due to the presence of economies of scale and the fact that smaller and isolated systems are in many cases mostly dependent on oil imports and find it more difficult to diversify sources of energy.

- The interacted term between GDP per capita and power system size is negative, revealing decreasing returns to scale by the highest income countries - such as OECD countries - which have already achieved close to universal access and face an exponentially increasing cost in connecting each new consumer as they approach full coverage. The explanatory power of these variables is very high, reaching 90% in the preferred specification of random effects.

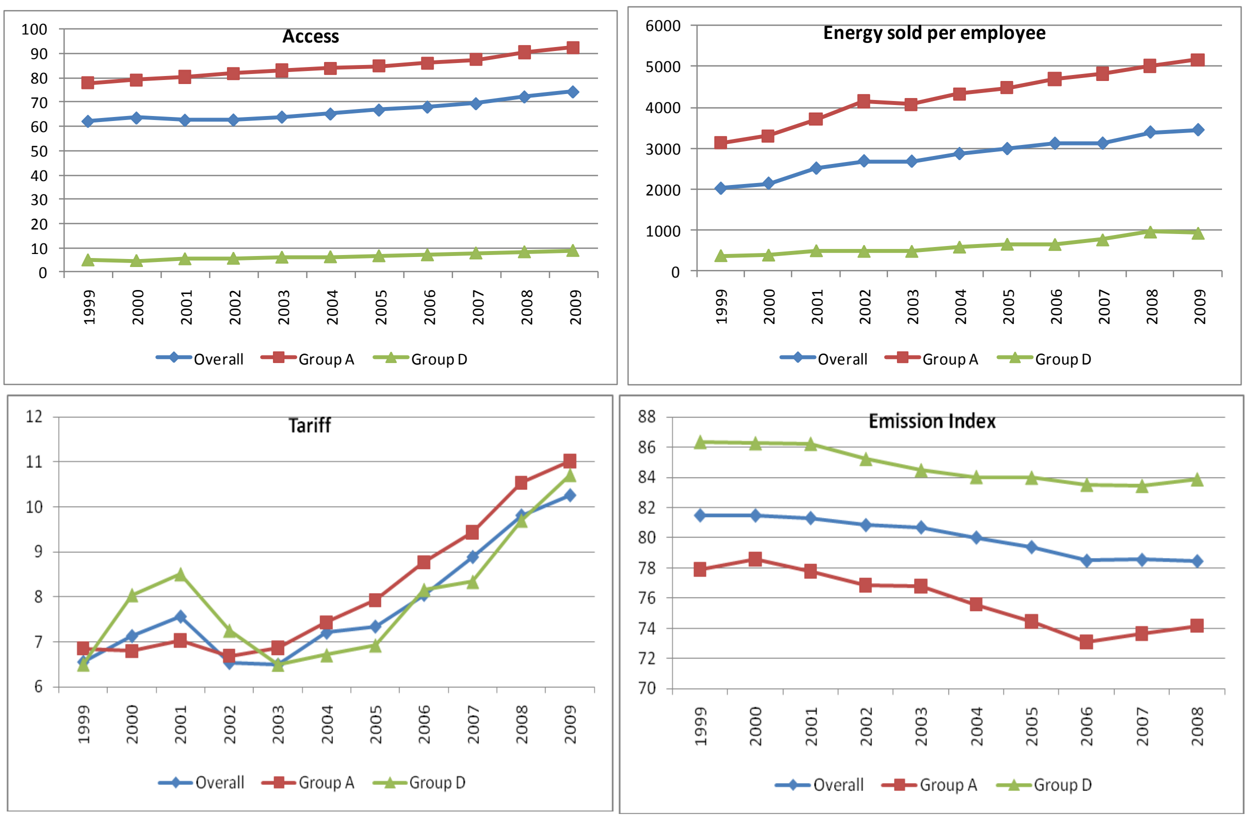
Table B summarises the analytical evidence for these results.

Table B
Summary of Analytical Evidence

	Access		Labor Productivity		Tariff		Emissions Index	
Group	A	D	A	D	A	D	A	D
VERTICAL UNBUNDLING (EITHER PARTIAL OR FULL)								
Unbundling	-		-		+**		+*	
Unbundling* Group	+***	-***	-	+*	-	+	-**	+**
FULL VERTICAL UNBUNDLING								
Full Unbundling	+		-*		+***		+	
Full Unbundling* Group	+***	-***	-	+*	-***	+***	-***	+***
DEGREE OF DISAGGREGATION								
Disaggregation	+***		+		-***		-***	
Disaggregation* Group	+***	-***	+**	-	+	-	-***	-***
REGULATION								
Regulation	+***		+***		+***		-***	
Regulation* Group	+***	-***	+***	-**	-***	+***	+***	-***
PRIVATIZATION								
Privatization	+***		+***		+**		+***	
Privatization* Group	+	-*	+**	-**	+	-	-	+
CONTROL VARIABLES								
GDP per capita	+***		+***		+***		+	
Installed capacity	+***		+***		+***		-***	
GDP per capita*Capacity	-***		-***		-***		+***	
EXPLANATORY POWER								
Within R^2 (fixed effect)	64		90		54		22	
Between R^2 (random effect)	92		77		52		30	

Figure A compares the average performance levels of all the selected countries as a group with the average levels for the country Groups A and D over the ten-year period 1999 to 2009 in terms of the four main performance indicators: access, energy sold per employee, tariff, and emission index. Group A countries consistently outperform Group D countries on all indicators. Yet the trends for all performance indicators are rising – improving – for all country groups over this period.

Figure A
Power Sector Performance Indicators over Time



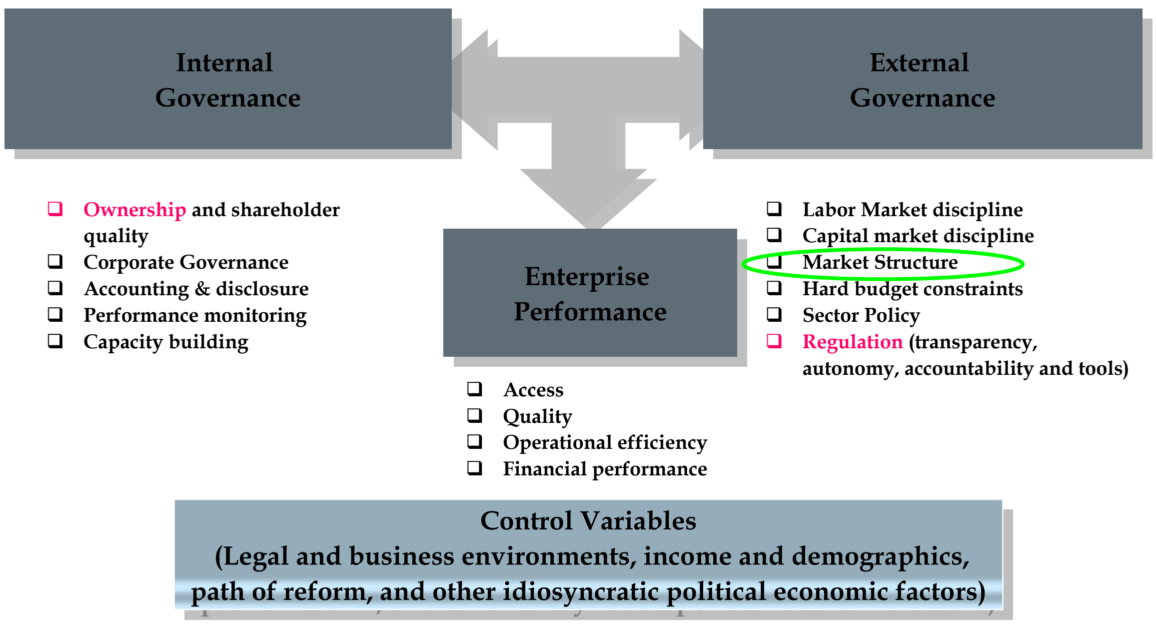
Revisiting Policy Options on the Market Structure in the Power Sector

1. Introduction

This study represents a crucial component of a work program on "How to improve the performance of power sector provider". One of the key objectives of the work program is to explore the links and the interaction between internal and external governance and the performance of infrastructure service providers, as illustrated in Figure 1. Market structure is one of the key external governance mechanisms that can impose discipline to infrastructure improve performance.

Figure 1

An holistic Approach to Governance Evaluation Framework at the Enterprise Level



The design of market structure is often the starting point for the overall reform in the power sector, having a major effect in shaping all other key decisions, including the design and structure of the contracts as well as the decisions on prices. Accordingly, market structure has a powerful influence on whether and to what extent the electricity sector can achieve improvements in performance.

Market structure matters for performance in the power sector. If poor decisions are made on the electricity market structure, technology and timing of investment, cost increases will be passed to consumers with negative consequences for economic performance and social welfare. This proposal will look in a systematic way at the links between alternative market structures and their links with access, quality, operational and financial performance in the electricity sector. The institutional model of a publicly owned monopoly industry means risks are shifted disproportionately to consumers or taxpayers. Because of information asymmetries, the regulator is unlikely to get a complete picture of costs and potential efficiency gains.

Alternative electricity market models have emerged. The first is competition for access to the electricity market, including variations of the single buyer model. The private sector is encouraged to invest in new power-generation capacity through tenders or auctions. If well managed, competition can result in improved efficiencies in technology and investment choices**.** When a comprehensive restructuring of their power sectors is not technically feasible or politically desirable the single buyer is the only remaining alternative to attract private capital. Arizu *et al* (2005) provide an extensive review of how this concept was implemented and changed over time, and what arrangements have been introduced to overcome its drawbacks, while preserving its positive attributes. The second electricity market model involves competition between electricity generators and suppliers to provide electricity to consumers. In the latter model, competition is managed through a power exchange or bilateral markets or both, and market risks can be managed through derivative financial markets.

About half of the 150 developing countries have embarked on reforming their power markets since the early 1990s in response to poor technical and financial performance and lack of public financing needed to expand power supply (Besant-Jones, 2006). Most of these countries have restructured their power supply arrangements by at least some or full vertical unbundling of generation, transmission and distribution. The remaining countries have retained the traditional structure of a full or partial vertically integrated monopoly, in some cases because they felt it impossible or undesirable to embark on any reform strategy that entails opening electricity production or sales to private participants. A new emerging trend in a few developing countries is to revert from an unbundled structure towards a vertically integrated one (Vagliasindi and Izaguirre, 2007).

It is now time to revisit which alternative market structures performed best in order to better inform the policy dialogue between donors and the Bank's client countries. The results of this work are expected to be crucial in providing policy advice, by offering alternative options to policy makers based on the lessons learned from the taxonomy of different market structures. The primary audience of this work is represented by policy makers in the client countries and the international community of experts in energy infrastructure. The project is also intended to provide insights to better form policy recommendations/operational guidelines in this area that would be useful for International Financial Institutions in their policy dialogue with the client countries.

1.1. What does theory suggest on the costs and benefits of alternative market structures?

The existing variety of power supply structures reflects differing views and a degree of theoretical ambiguity in the economic literature on the effectiveness of unbundling and competition in network industries on issues such as gains from competition versus economies of co-ordination in vertically integrated systems. In practice, the benefits of each reform and restructuring must more than compensate for the increase in transaction costs of unbundling vertically integrated systems.

The traditional economic arguments against unbundling power systems were based on the concept of: i) electricity as a public good, as vertical integration will better ensure service reliability and uniform standards and procedure among interconnecting segments of the grid, **ii) natural monopoly,** as a means to avoid wasteful duplication of transmission and distribution (T&D) networks, **iii) economies of scale,** as horizontal integration supports the large size and capital requirement of efficient plants (hydro and coal base load plants), though such arguments are weakened when smaller combined cycle units became more cost effective, **iv) economies of scope,** as tight coordination (centralized investment and operation) translates into savings in metering, billing etc., **v) economies of transaction costs,** due to reduced costs due to asset specificity and incompleteness of contracts, and **vii) better management of investment and operational risks**.

But these arguments might not hold in some country and power market conditions because they are based on specific underlying assumptions that are not valid in these conditions, including: **i)** a lower cost of capital for the power utility, **ii)** the creditworthiness of a power utility requires that it be the sole buyer of generated power, **iii)** third party access should be prevented to support cross-subsidies among consumers that are mandated under government policies, **iv)** savings coming from competitive pressures (to reduce costs) are minor when compared to economies of scale and scope. They ignore post-restructuring changes, including the introduction of new regulatory policies and market structures that can solve the "problem" of unbundling (but whose overall impact might go either way). For instance, whereas integration may increase retail market power, this may not be detrimental, preserving or even enhancing generation investment incentives (Dupuy, 2006). In practice, there may be trade-offs between these objectives in developing countries, notably between economic efficiency and social objectives, that could be useful to be incorporated into operational guidance.

An alternative view is based on financial risk management, rather than economic concepts, that an optimal degree of integration can exist. Such an optimal degree of integration (Chao, Oren and Wilson, 2005 and 2008) lies between total integration and total unbundling. The degree depends on the mutual interest of generators and retail services providers in mitigating "systemic" risks, through the provision of (physical and financial) reserves and contracting under unbundling. This view asserts that such risks were not sufficiently taken into account when unbundling began. Retail utilities need this integration even when the cost of energy is passed through because they continue to serve a large contingent of core customers – mostly residential and small consumers – who rely on inter-temporal smoothing of supply costs in their retail rates.

1.2 What does empirical evidence suggest on the costs and benefits of alternative market structures?

The economic literature reviewed above suggests that there were substantial vertical economies associated with networks. However, to date there is limited evidence on the (relative) success in the implementation of vertical unbundling and its links with enhanced investment (particularly in transmission) and ultimately the improvement of power utilities performance, particularly in the cases where short term privatization is out of the realm of possibilities.

The (relative) success need to be assessed against the objectives of unbundling – which could have been to enhance transparency and governance, attract private sector investment, and/or to create a competitive market and ultimately its impact on performance. In some cases restructuring had the purpose of creating an enabling environment to attract private sector investment taking some level of market risks and/or commitments to efficiency improvements. Transferring to the private investor market risks requires greater transparency and predictability, which may be more difficult to obtain in a sector with an integrated monopoly power utility to which for example the private generator is obliged to sell.

Little analysis of empirical evidence about unbundling in power markets has been published, and this analysis is focused on economically advanced countries. Kwoka (2002) studied extensively the US system to measure economies of coordination between generation and distribution for about 150 US electric utilities with a wide range of size and degree of vertical integration that operate in regional power pools. He concluded that the least integrated distributors incur on average significantly higher total costs than the most integrated (6.27 cents/kWh versus 5.35 cents/kWh). But this difference increased markedly with utility size. The smallest utilities – who are nearer in size to utilities in developing countries - showed small diseconomies of coordination. The largest utilities showed very substantial economies of coordination (over a level of 50%). Two recent studies report much lower economies of vertical integration. Nemoto and Goto (2004) estimates that the cost efficiency gain from vertical integration in the case of 9 Japanese utilities varies from 0.2% to about 3%. Jara-Diaz et al (2004) based on the sample of Spanish electricity utilities conclude that about 7% of costs can be saved from joint generation and distribution. Despite providing useful insights, these studies are not really relevant to developing countries, however, because of the large differences in economic conditions between advanced and developing countries.

Two recent studies expand the available empirical analysis of vertical unbundling. Arocena et al (2009) studied the economies of integration (economies of scale and of scope) for a group of 116 investor owned power utilities the United States based on data for the year 2001. The results provided a reference for the expected cost of unbundling. They concluded that vertical integration provided a substantial and significant cost saving relative to vertical unbundling, and also that horizontal integration in the generation sector provided a further – but smaller – cost saving relative to horizontal unbundling. Taken together, global savings from integration amount to as much as 12.5% of costs for the sample average firm. This level indicates a level of anticipated gains needed to justify unbundling. Meyer (2010) applied a frontier benchmarking approach to measure the economies of scope between the vertical stages of electricity supply in the U.S. electric industry. The study concluded that the costs of separating the generation stage from networks and retail stages compared to integration is strongly related to the size of the utility. For the larger utilities in the sample, this type of separation lowers their overall costs because the gains exceed synergy losses, whereas for the smaller utilities this type of separation increases their overall costs. The threshold size that divides utilities whose costs decrease from those that increase is about 10,000 to 12,000 GWh of annual generation and distribution.

There is also some published evidence about the links between integrated power systems and country-level corruption for EU. Both for the EU-15 member states and the NMS-10 member states, the more corrupt the countries the more likely they are to choose a weak unbundling regime, even though the result are stronger in the case of EU-15 member states (van Koten and Ortmann, 2007).

A main unanswered question about unbundling and establishment of liberalized wholesale markets is whether in the long run they provide adequate investments in capacity. The California crisis brought this issue powerfully forward. But the basic problem that generation companies face higher capital costs now than the utilities did in the regulated era is increasingly important in other countries where some generators are in financial distress.

In developing countries there is evidence of the benefits brought by unbundling when it is associated with increased investment in generation and transmission. The first result holds mainly when the institutional environment is sufficiently robust to attract credible Independent Power Producers (IPPs). In this context, opening the generation segment of the market to competition may help cash strapped governments to increase investment in generation. The key problem -- particularly acute in challenging institutional environments -- is the high costs of procuring IPPs, resulting in charges that eat up a large portion of the revenues of the distribution companies that must purchase the electricity generated. The Tanzanian utility, TANESCO, for example, paid about 70% of its total average monthly revenues in 2005 to meet IPP charges; by 2006, these had risen to an astonishing 95 percent (Ghanadan and Eberhard, 2008). There is also anecdotal evidence that vertically integrated structures invest less in transmission, though this link needs to be tested.

1.3 What do we know about the taxonomy of market structures?

***The distinction between integration and unbundling of power supply arrangements is not clear cut in practice, as several different structures exist around the world*:**

- vertical unbundling without horizontal unbundling (but not the reverse);
- partial vertical unbundling (generation and transmission separated from distribution, generation separated from transmission and distribution, etc);
- full vertical and horizontal unbundling in generation (and integration of transmission & distribution);
- vertical unbundling in lesser forms than ownership unbundling, such as accounting, management, legal (holding company) unbundling;

- unbundling of retail supply from distribution, and then some re-integration of generation with supply for risk management, keeping transmission and distribution unbundled;

- unbundling of generation services in wholesale power markets.

In addition, unbundling can take lesser forms than full ownership unbundling that is discussed above. These forms include by legal/corporate means in holding companies, by internal management structure, and just by accounts. The conventional view is that the potential benefits from unbundling are greatest with full ownership unbundling, and that these benefits decline with lesser forms of unbundling. Where country and market conditions cannot support privatization of fully unbundled power suppliers in the highly sub-optimal environments found in many developing countries, other forms of unbundling and associated public-private participation have to be adopted as the best solutions in practice – even if second-best in theory.

The objectives of unbundling and restructuring vary. In some cases restructuring had the purpose of creating an enabling environment to attract private sector investment taking some level of market risks and/or commitments to efficiency improvements. Transferring to the private investor market risks requires greater transparency and predictability, which may be more difficult to obtain in a sector with an integrated monopoly power utility to which for example the private generator is obliged to sell.

So far we do not have a comprehensive taxonomy of all the different forms of horizontal and vertical unbundling. We do, however, know that countries that have embarked on reform have generally progressed to different stages, which can be categorized in ascending extent of reform as follows (for more details, see Besant-Jones, 2006):

- **Vertical integration:** A vertically integrated monopolist.

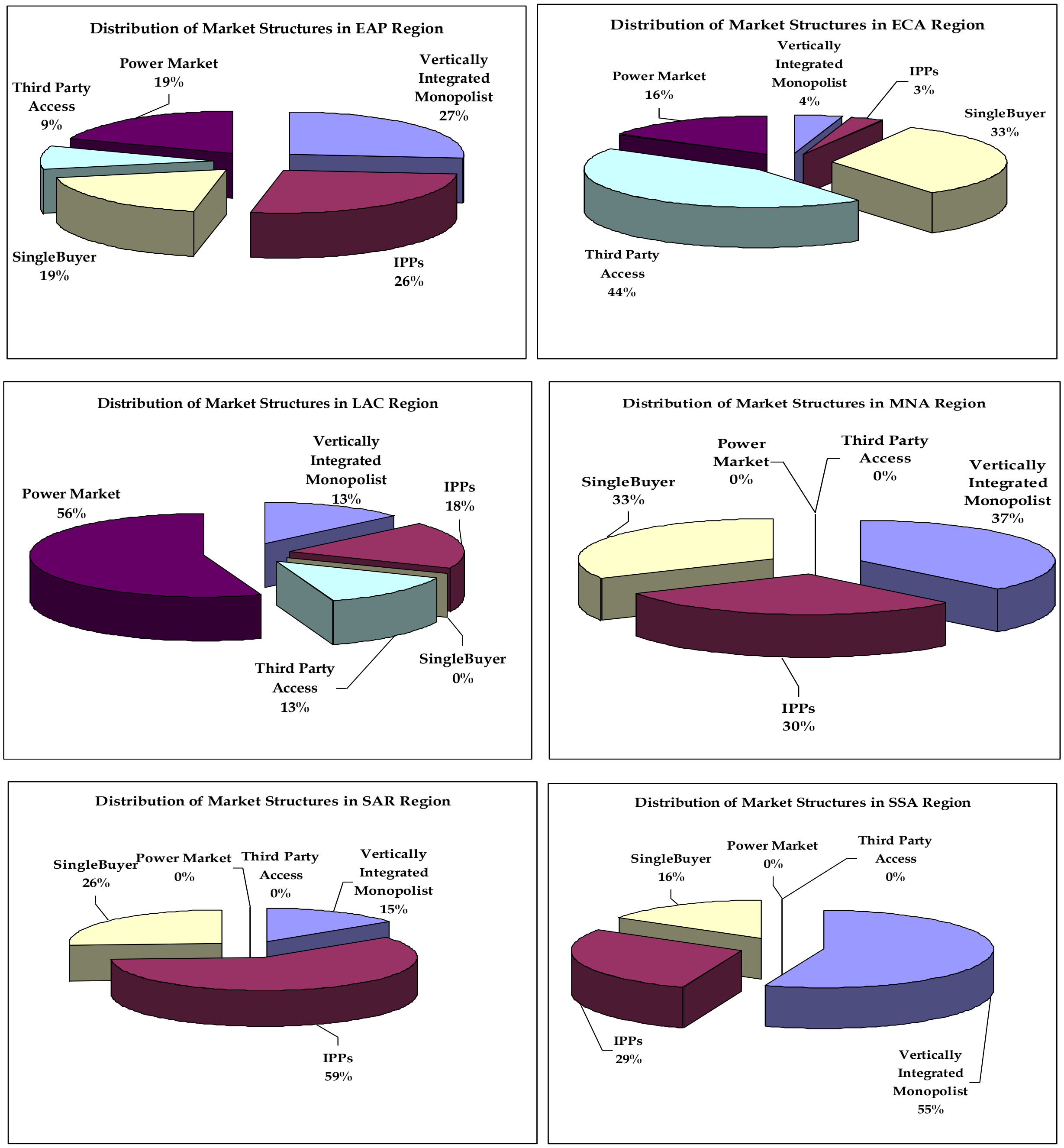
- **Vertical integration with IPPs:** A vertically integrated monopolist with independent power producers (IPPs) that sell power to it.

- **Some extent of vertical and horizontal unbundling:** A national generation, transmission or distribution entity, a combined national generation and transmission entity or a combined transmission and distribution entity acting as the only wholesale power trader (single buyer) with IPPs that sell power to it and regional distribution entities unbundled from the monopolist that buy power from it.

- **Extensive vertical and horizontal unbundling:** Many distribution entities and generation entities and a transmission entity formed from unbundling the monopolist, in which the transmission entity acts as a single buyer of power from the generators and IPPs and sells power to the distribution entities and large users of power.

- **Power market:** An organized market of generation entities, distribution entities and large users in which power is traded competitively, supported by a transmission entity, a power system operator and a power market administrator.

Figure 2
Distribution of Stages of Reforms and Market Structures in the Power Sector by Regions



Source: authors' elaboration based on Besant-Jones (2006)

Reform to date, though, is unevenly spread among regions (see Figure 2). Countries in Latin America and the Caribbean and in Europe and Central Asia account for all the countries that have progressed to the two most advanced stages described above. In Africa, South Asia and the Middle East, progress to date is generally limited to the first two stages with long-term contracts by IPPs to supply incumbent utilities. Some countries in East Asia, for example, have made tentative steps to further their reforms.

The current distribution of power markets around intermediate structures between full integration and full unbundling suggests that there has not been a linear path to reform in practice. Instead, many developing countries may retain intermediate structures for foreseeable future. This possibility exposes a large gap in understanding about power market structures, since most theoretical work has focused on the two extreme structures and there is limited evidence on the impact of unbundling for developing countries. For instance, Nagayama (2007) finds that the introduction of IPPs contributes to lowering the industrial prices at least in some developing regions (ECA) whereas unbundling of generation from transmission increased industrial and residential prices in the same regions. Basically, it appears that unbundling in most developing countries is undertaken for reasons other than or in addition to the introduction of competition, which is the purpose generally advanced in the theoretical literature. One of the purposes of the proposed task is therefore to obtain a better understanding of these developments and the policy requirements for successful outcomes under the intermediate market structures in the economic, social and political conditions of developing countries. More detailed analysis is needed to better understand the costs and benefits of unbundling and the characteristics of well functioning unbundled power systems.

2. *Objectives*

The objective of this study is twofold: **to map the existing approach to vertical and horizontal unbundling adopted by developing countries**, and **to undertake econometric analysis and detailed case studies to better understand and assess the desirability of unbundling under developing country conditions.**

The specifics objectives are:

- ***To develop a taxonomy of the existing power market structures***, as shown by the extent of vertical and horizontal unbundling found among restructured power systems, across developing countries;

- ***To design an analytical framework for assessing the desirability of unbundling or – once unbundled - and re-integration under the variety of economic conditions found among developing countries***, by comparing economic costs and benefits, also accounting for transaction costs and financial risk management considerations. The analytical framework will use *inter alia* specific performance indicators to guide the comparisons across different market structures;

- ***To propose insights to operational guidance on alternative market structures based on relevant criteria***, in particular on initial conditions including but not restricted to power system size and income per capita, which can address issues such as whether there are solid foundations for recommending vertical unbundling for small power systems in low-income countries, particularly in the absence of short term privatization prospects. The proposed policy recommendations will be tailored to the specific taxonomy of market structures that characterize the electricity sector in developing countries.

2.1 Key Questions

To achieve such objectives, we need to address the questions below:

- Is there a credible empirical basis for selecting ***a threshold power system size and per capita income level*** below which market competition is not expected to be worthwhile, and under which alternative agreements (e.g. PPAs with IPPs selling to an integrated supplier) may be preferable?

- Is there ***a threshold power system size*** below which increased transaction costs begin to exceed the benefits of unbundling the power supply industry? Is power system size the primary consideration for determining whether vertical unbundling of a power supply industry is worthwhile? If not what other considerations are relevant?

- Should ***threshold levels for power system size and per capita national income*** be adopted as an operational guide to the choice of unbundling? In particular, should vertical unbundling be recommended for small power systems in low-income countries, particularly in the absence of short term privatization prospects?

- How should the policy recommendations be adapted for a country that wants to move to privatization of power supply and transfer market risks to private generators, and alternatively how should policy recommendations be adapted for a country where privatization of power supply is not possible?

- Which policy instruments could be used to tackle policy issues related to the taxonomy of the different market structures? In particular, what can be done to improve the key decisions on contracts and prices "internalized" within the firm through the existing "structure/ownership" and the ones that have been delegated to outside "contracts/market rules", depending on the transaction costs involved?

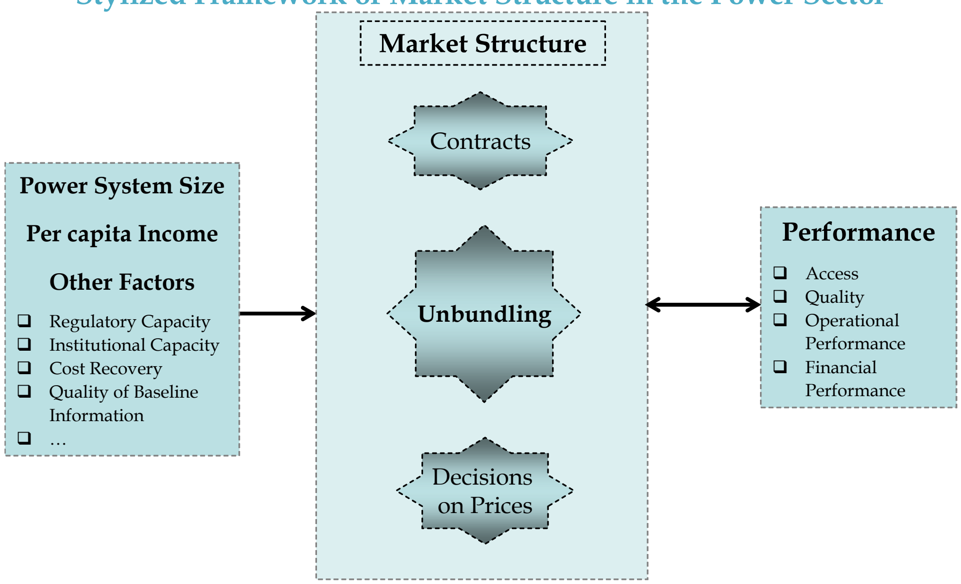
2.2 Analytical Framework

This study examines in detail some selected issues related to market structure in the power sector. While recognizing the potential influence of additional issues pertaining to the broader set of reforms in the power sector, the study applies the "ceteris paribus" approach. The stylized approach to examine market structure in the power sector is illustrated in Figure 3. As the form and extent of unbundling determines the market structure, particular attention is devoted to the analysis of key decisions through the lens "structure/ownership" vis-à-vis "contracts/market rules". Namely, the analysis separates within each market structure the key decisions that have been "internalized" within the firm through the existing "structure/ownership" from the ones that have been delegated to outside "contracts/market rules", depending on the transaction costs involved.

The key decisions that are included in the analytical framework pertain to the contracts between the newly unbundled entities and decisions about prices. Unbundling decisions entails also key decisions about the contracts that are be allowed –or in some cases are compulsory – between the unbundled entities in generation, transmission and distribution. Unbundling implies a decision on prices, related to generation auctions, as well as to the prices used for wholesale prices (and whether these are passed through to end users).

Other considerations can come into play in determining the market structure. In the case of a switch from one market structure to another, transitional costs may be also a relevant consideration in deciding the market structure. For instance, in moving from a single buyer model to a wholesale market stranded costs – including generation-related costs that become unrecoverable due to restructuring and retail competition – must be evaluated and settled. Finally, the existence of a regional power market may affect the choice of a country's market structure. Such issues will be considered on a case by case basis.

Figure 3
Stylized Framework of Market Structure in the Power Sector



Unbundling is not an end itself, but rather a means to achieve better performance. Accordingly, the key objective of the analytical framework is to explore the links between alternative market structures and performance (in terms of access, price, quality, technical and financial performance). The results are crucial for providing policy advice, by offering alternative options to policy makers based on the lessons learned from the taxonomy of different market structures, tailored to different national peculiarities.

3. Methodology

Jamasb et al. (2004) classified the approaches to analysing electricity reforms into three broad categories: (i) econometric methods, (ii) efficiency and productivity analysis methods, and (iii) comparative case studies. They argue that econometric studies are best suited to the analysis of well-defined issues and the testing of hypotheses through statistical analysis of reform determinants and performance. Efficiency and productivity analyses are suitable for measuring the effectiveness with which inputs are transformed into outputs, relative to best practice. Jamasb et al. (2004) also maintain that single or multi-country case studies are suitable when in-depth investigation or qualitative analysis is needed. Within this classification, our study well suits the first and third category. Both an analytical and case study approach will be used to investigate the design of market structure in detail. The analytical approach is used to draw robust links between the alternative market structures and performance (as described in section 3.1 below).

The case study approach is suited to dealing with the strong influence of country-specific effects on power market performance and reform outcomes. A key disadvantage of this approach is that it will be hard to generalize results, in light of the small sample of enterprises. However, we will try to the extent possible to overcome some of the limitations of the case studies approach through a careful design of the sampling frame (as described in section 3.2 below).

3.1 Analytical Approach

Our study proposes an analytical approach to model market structure (M), together with ownership (O), regulation, (R) controlling for several variables, as determinants of performance across several indicators of performance (P), including access, operational and financial performance and environmental sustainability.

(1) $P_t = f(O_t, M_t, R_t, E_t)$

where:

P = performance variables (e.g. access, operational and financial efficiency and environmental indicators)

O = ownership (e.g. public vs private ownership)

M = market structure (e.g. degree of vertical integration, degree of concentration)

R = introduction of an autonomous regulator

E = endowment (e.g size of the system)

This methodology represents a novelty with respect to most empirical studies. To date, there has been limited empirical work including market structure variables in the analysis, particularly in the case of developing countries. Only a selected number of variables of performance have been used in the literature and there is no evidence reported on the impact of reforms in terms of environmental sustainability.

As it is a priori difficult to make assumptions about the explanatory power of the selected independent variables including various indicators of unbundling and other sector reforms on the dependent variables, so that we use both fixed and random effect model (see Appendix 1 for a description of both approaches). The study uses GDP per capita and installed capacity as control variables on the basis described in Section 3.2 below.

3.2 Case Study Approach

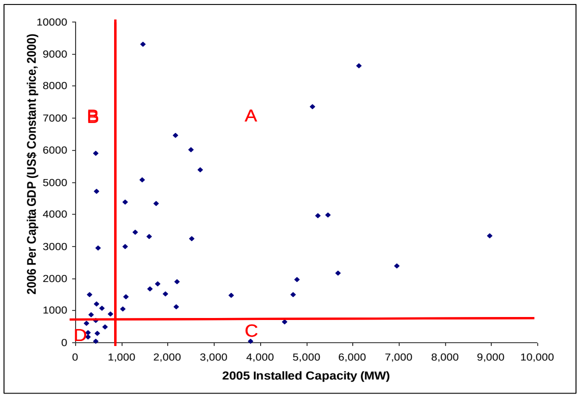
A series of country case studies is also carried out to support the analytical approach reported in the previous section. The selected countries cover all six developing country regions, and thereby reflect broad regional features such as Africa's low access rates and underdeveloped transmission networks; Europe and Central Asia's (ECA) full access rates, highly developed transmission interconnections, historically surplus generating capacity, and the strong influence from the EU and Russia; Latin America and the Caribbean's (LAC) leadership in market reform and large amounts of hydropower capacity; East Asia's and South Asia's high growth in power demand and therefore need for generation capacity; and Middle east and North Africa's (MENA) emergence as a strategic crossroads in energy trade.

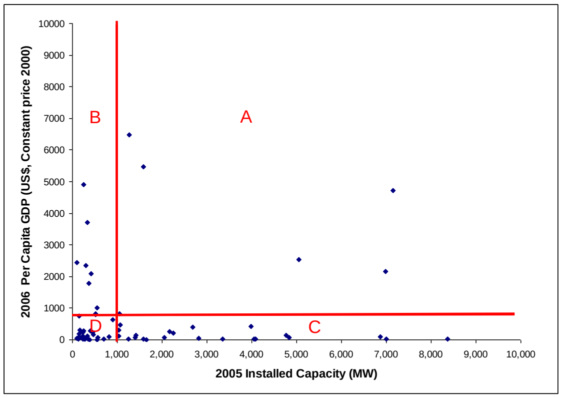
The case studies are predicated on the hypothesis that power system size and per capita income appear to influence the choice of power market structure in developing countries. A clear empirical threshold for unbundling power systems currently appears to separate developing countries into groups which is defined in terms of power system size of 1000 MW and country annual per capita income of $900. The majority of countries, 49 out of 70 countries with unbundled power systems, lies above both of these thresholds (in the A quadrant as reported in Figure 4 (a)). From the distribution of countries for unbundled and vertically integrated power market structure, it can be surmised that power system size has a relatively stronger influence than per capita income on determining the market structures. Country income level, on the other hand, may have a relatively stronger influence than power system size on the roles of the public and private sectors and market regulation.

The performance of countries with unbundled power sectors is compared to the counterfactual of countries that have a vertically integrated structure. This comparison is undertaken within each of the four groups of countries determined by the threshold levels of system size and country annual per capita income (as shown in Figure 4). We refer to the four groups of countries as Groups A to D. Group A consists of countries in which both power system size and per capita income are above the threshold levels, Groups B and C are the ones for which either power system size or per capita income is below one of the threshold level and Group D is the one for which both power system size and per capita income are both below the threshold levels. Additional control variables including ownership structure but more importantly governance variables will be taken into account, including those able to capture institutional and political economy dimensions.

Figure 4
System size and income for unbundled and vertically integrated systems

a) unbundled systems **(b) vertically integrated systems**





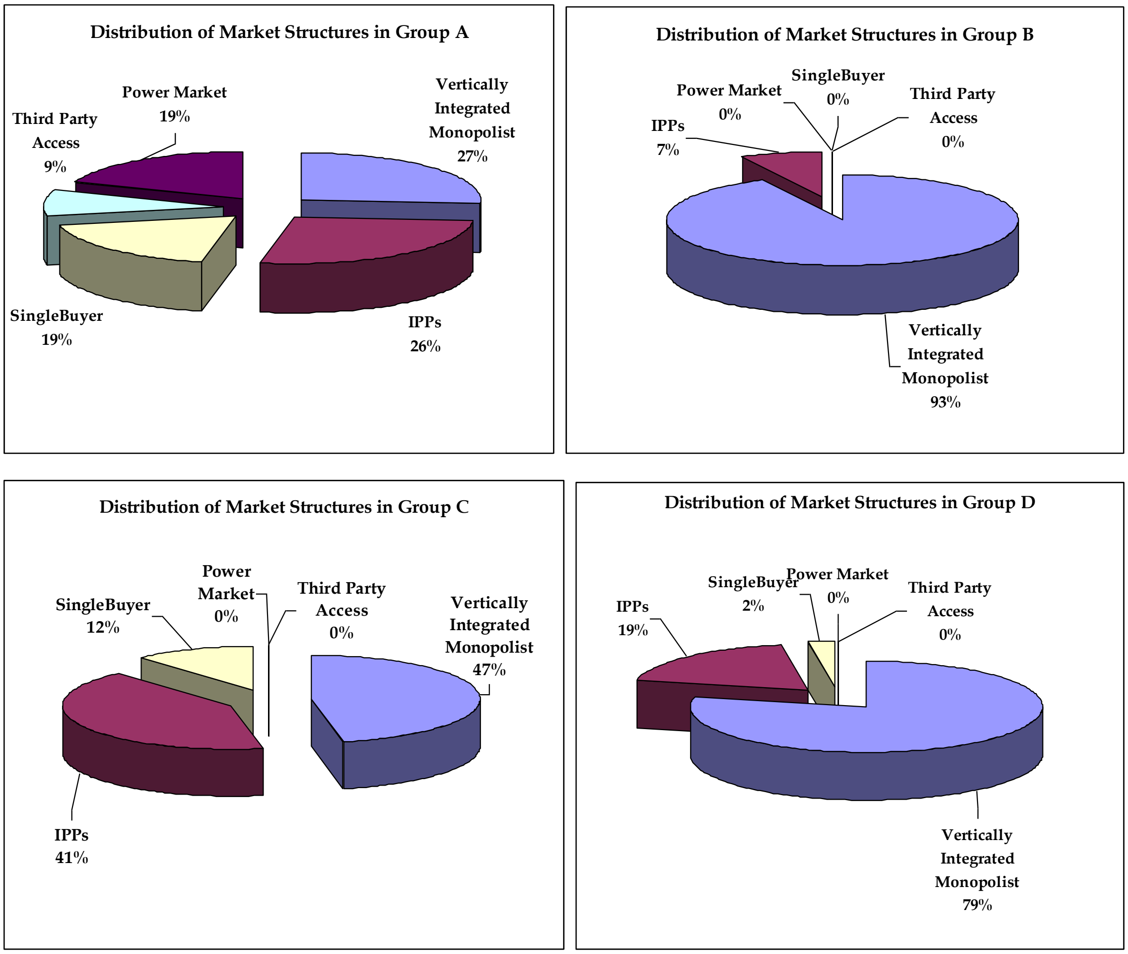
Source: authors' updated information based on Besant-Jones (2006)

Unbundling can also be expected to enhance governance through increased transparency and reduction of the scope for corruption (e.g. by making subsidies and cross subsidies more explicit)**.** In this context we will explore the link between unbundling and alternative indicators of country level governance. As shown below, significant differences emerge between country groups:

- ***About 70 countries (68 out of 155) lie above both threshold levels*** of power system size and per capita income (Group A). They are perceived to have a medium level of corruption (the Transparency International Corruption Perceptions Index in 2006 average is equal to 3.7 - which indicates the presence of some degree corruption)

- ***43 countries lie below both threshold levels*** of power system size and per capita income (Group D). They are perceived to have a relatively high level of corruption (the Transparency International Corruption Perceptions Index in 2006 average is equal to 2.6 – which indicates the presence of rampant corruption)

Figure 5
Distribution of Stages of Reforms in the Power Sector by system size and income



Source: authors' elaboration based on Besant-Jones (2006)

More detailed analysis is needed to better understand the costs and benefits of unbundling and the characteristics of well functioning unbundled power systems. The analytical framework will define *inter alia* specific performance indicators both at the enterprise and country level that will be used to compare outcomes across different market structures. Figure 5 shows powerfully that all the countries that have advanced at power sector reforms lie in Group A. Of the poor countries characterized by a small system (Group D), about 80% are characterized by a vertically integrated structure, and less than 20% have introduced IPPs and only 2% have adopted a single buyer model.

The case studies proposed for each of the groups are as follows:

Group A: To ensure a representative sample for this region, the following ten countries have been selected: Egypt, Indonesia, Korea and South Africa, for vertically integrated cases, Czech Republic and for some partial form of unbundling and Argentina, Brazil, Chile Peru and Turkey for the unbundled cases. The performance of **Czech Republic, Egypt, Korea, Indonesia** and **South Africa** (all of which display either a vertically integrated structure or simply legal unbundling, mainly under a holding structure) is compared with **Argentina,**

Brazil, Chile, Peru and **Turkey** that, instead, have moved reforms forward by introducing a competitive wholesale market. **Chile** in 1982 unbundled the sector structure into generation and transmission companies and distribution utilities. The distribution utilities were divided according to the service areas, but they were not granted exclusive rights. Between 1983 and 1989, Government then privatized most of the generation, transmission and distribution segments, so that all the generation, transmission and distribution was in the hands of the private sector through local and international investors, and created a mandatory power pool administered by a system operator CDEC. **Argentina** implemented extensive reforms in the early 1990s, including vertical and horizontal unbundling of generation, transmission and distribution and opening up of all segments to the private sector. In **Peru**, the structural reform process that started in 1992 led the unbundling of the vertically integrated state monopoly into generation, transmission and distribution and to the introduction of private operators and free entry and open access**.** **Brazil** proceeded in 2005 to the unbundling of Electrobrás into six holding companies and 14 generation and transmission companies. Eletrobrás retained the ownership of the transmission grid, the Brazilian part of the binational Itaipu dam and hydroelectric power station, the nuclear power plants and CEPEL's research and development activities. **In Turkey,** a competitive wholesale electricity market went into operation in 2006, after in 2001, TEAS was unbundled into three separate state-owned entities: 1) The Electricity Generation Company of Turkey (EUAS) for generation, 2) The Turkish Electricity Transmission company (TEIAS) for transmission and dispatch, and 3) Turkish Electricity Trading and Contracting Company (TETAS) acts as single buyer of electricity sold under the PPAs, and it onsells this electricity to the distribution companies.

- **Group B and C:** The performance of countries that have kept a vertically integrated structure, including **Barbados**, **Botswana, Cyprus and Zambia** are compared with selected countries from East Asia, including **Vietnam,** some of the **Indian** power sector regional structures (**Andhra Pradesh, Gujarat and West Bengal**) that went further in the process of unbundling and **Jordan** from the MNA region which unbundled NEPCO into three companies: (i) a company to own and operate the transmission network and system operation, as well as act as a single buyer for bulk power, which inherited NEPCO's name; (ii) the Central Electric Generating Company (CEGCO) that took over all the public generating capacity; and (iii) the Electricity Distribution Company (EDCO) that took over JEA/NEPCO's distribution activities. This was followed by a major campaign to transfer the state's ownership to the private sector that culminated in 2007 with the sale of 51% of the shares in CEGCO, the state's 45% shareholding in IDECO, and the state's 100% shareholding in EDCO. This move was continued with signing agreements with the first IPP in 2007 and a second IPP in 2009. The proposed case studies proposed interesting features to be further examined. **Andhra Pradesh** has made the best progress recently with improving performance under public ownership. Andhra Pradesh has taken the lead in combating theft of power. The Government and the power companies have implemented impressive measures to control theft of electricity and root out corruption between utility employees and customers. In the case of **Gujarat**, the erstwhile Gujarat Electricity Board (GEB) was unbundled and reorganized into six successor entities in 2005, given by the Generation Company – Gujarat State Electricity Corporation Limited (GSECL) , the Transmission Company – Gujarat Energy Transmission Corporation Limited (GETCO) and four Distribution Companies, including Dakshin Gujarat Vij Company Limited (DGVCL), Madhya Gujarat Vij Company Limited (MGVCL), Uttar Gujarat Vij Company Limited (UGVCL) and Paschim Gujarat Vij Company Limited (PGVCL). After unbundling, that took place only in April 2007, **West Bengal** State Electricity Board (WBSEB) was separated in hydro generation (along with negligible generation from diesel and gas), transmission (including State Load Dispatch centre (SLDC) activities) and distribution, trading and bulk supply activities. In **Zambia**, ZANESCO was originally conceived as a step towards privatization but it became instrumental to drive commercialization and technical objectives, while maintaining public ownership. The comparative performance of countries with higher income but small system size, including **Barbados**, **Botswana and Cyprus,** that adopted a vertically integrated structure will allow us to test to what extent vertical integration has been successful in integrated small supplier regions as diverse as LAC, SSA and ECA and in terms of ownership with Barbados being private since the outset and Botswana and Cyprus fully state-owned.

- **Group D: Kenya**, and **Tanzania** are compared with **Uganda**, the only SSA country where a single buyer model has been introduced. The unbundling of **Uganda Electricity Board** (UEB) formally commenced on 1st April 2001. Successor companies were created and assets and liabilities of UEB were transferred to them as follows: i) Uganda Electricity Generation Co. Ltd (UEGCL) that owns the two major hydro-power plants at Nalubaale (180 MW) and Kiira (200 MW); Uganda Electricity Transmission Co. Ltd (UETCL) which owns and operates the transmission infrastructure above 33 kV.; ii) Uganda Electricity Distribution Co. Ltd (UEDCL) that owns and operates the distribution network at 33 kV and below; iii) Uganda Electricity Board (Statutory Corporation) that remained in place in order to wind up. **Tanzania** is one of the few countries that have undertaken a management contract. From 2002 to 2006 TANESCO was placed under a management contract with the private group NETGroup Solutions. The group doubled cash flow in two years mainly due to improved collections. Its subsequent efforts to extend the gains into other operational areas were unsuccessful due to external financial constraints to the contract, among other factors. The main external constraints were poor hydrological conditions that reduced hydropower production and therefore increased purchases of thermal power from the IPPs, the high costs of IPP power under the terms of the power purchase agreements, and tariff rates insufficient to allow TANESCO to invest in system improvements. In 2005, Government took TANESCO off the list of utilities for privatization. The addition of two thermal power plants developed by IPPs between 2002 and 2004 changed the primary energy mix from power generation in the country from being nearly 90% dependent on hydropower to 60% dependent on thermal power recently. Overall vertical integration in the sector has not changed much in **Kenya**, with transmission and distribution now bundled and generation unbundled into a few suppliers. As a result of the public sale of shares in KenGen and the entry of IPPs to the power market, the proportion of total installed generating capacity under private ownership increased from 16% in 2001 to 46% since 2007.

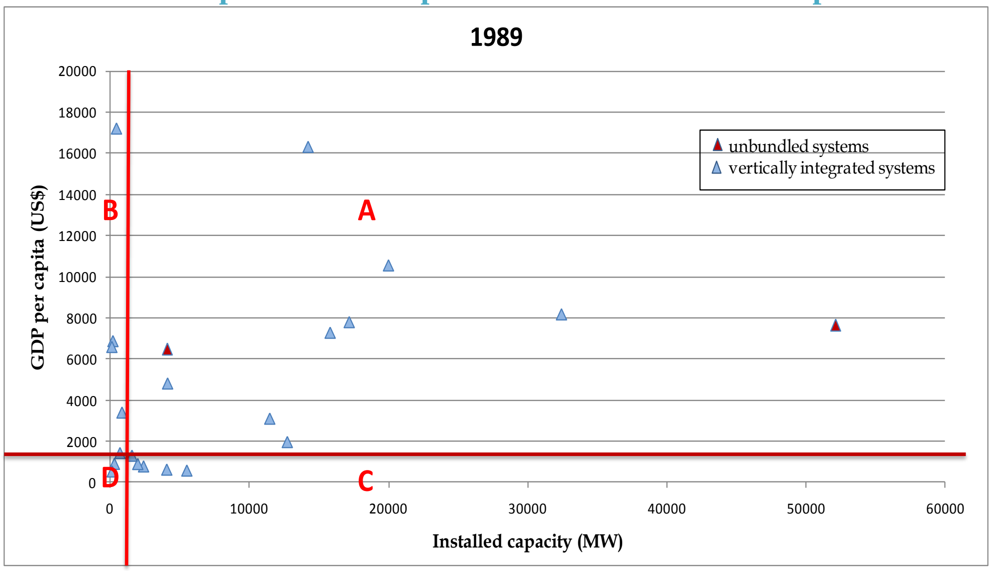
The taxonomy of the twenty-two proposed case studies is summarized in Table 1.

Table 1
Taxonomy of Case Studies

Group / Country	Type and Year of unbundling
Group A (large system size and high GDP per capita)	
Chile	Functional & Ownership 1982
Argentina	Functional & Ownership 1992
Peru	Functional & Ownership 1993
Brazil	Functional & Ownership 1995
Turkey	Functional & Management 2001
Egypt	Legal 2000
Czech Republic	Legal 2001
Indonesia	No Unbundling
Korea	No Unbundling
South Africa	No Unbundling
Groups B (small system size and high GDP per capita)	
Jordan (from B to A)	Functional & Ownership 1999
Cyprus	Legal 2004
Barbados	No Unbundling
Botswana	No Unbundling
Groups C (large system size and low GDP per capita)	
Indian State of Andhra Pradesh	Organisation 2001
Indian State of Gujarat (from C to A)	Organisation 2005
Vietnam (from C to A)	Organisation 2005
Indian State of West Bengal (from C to A)	Organisation 2007
Zambia	No Unbundling
Group D (small system size and low GDP per capita)	
Kenya (from D to B)	Legal 1999
Tanzania	No Unbundling
Uganda	Functional & Management 2002

Figures 6-8 show the scattered plots of our selected sample in the four groups over time, providing a snapshot for 1989, 1998 and 2008, distinguishing unbundled systems from vertically integrated ones.

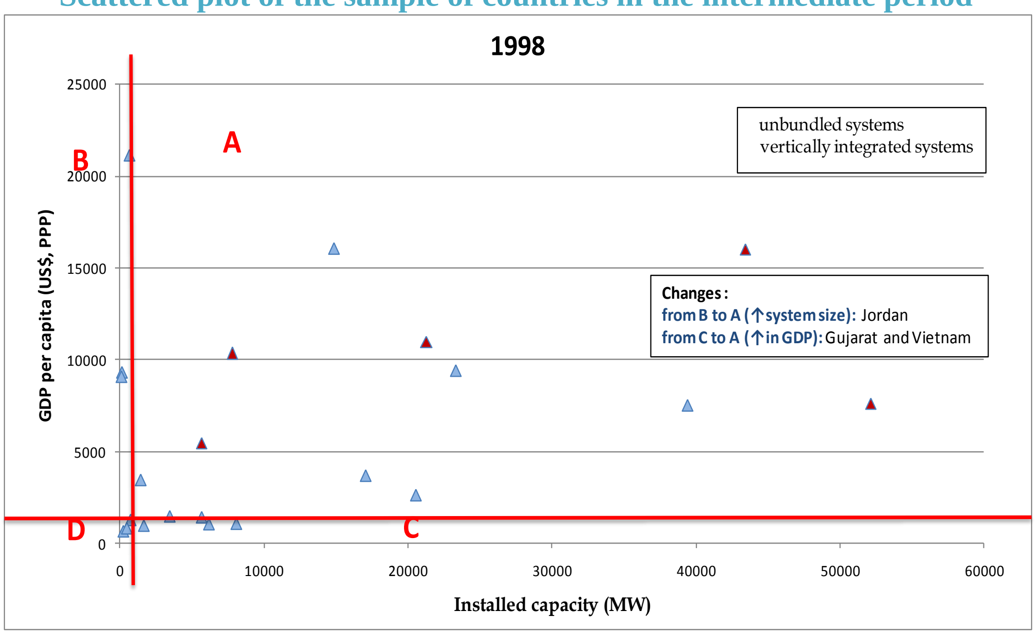
Figure 6
Scattered plot of the sample of countries in the initial period



Note: To separate the countries into different groups a threshold of 1178.5 MW for installed capacity, and $1429 for GDP per capita were applied. These thresholds represent for Group D approximately the lowest 25 percent of capacity and income of the sample.

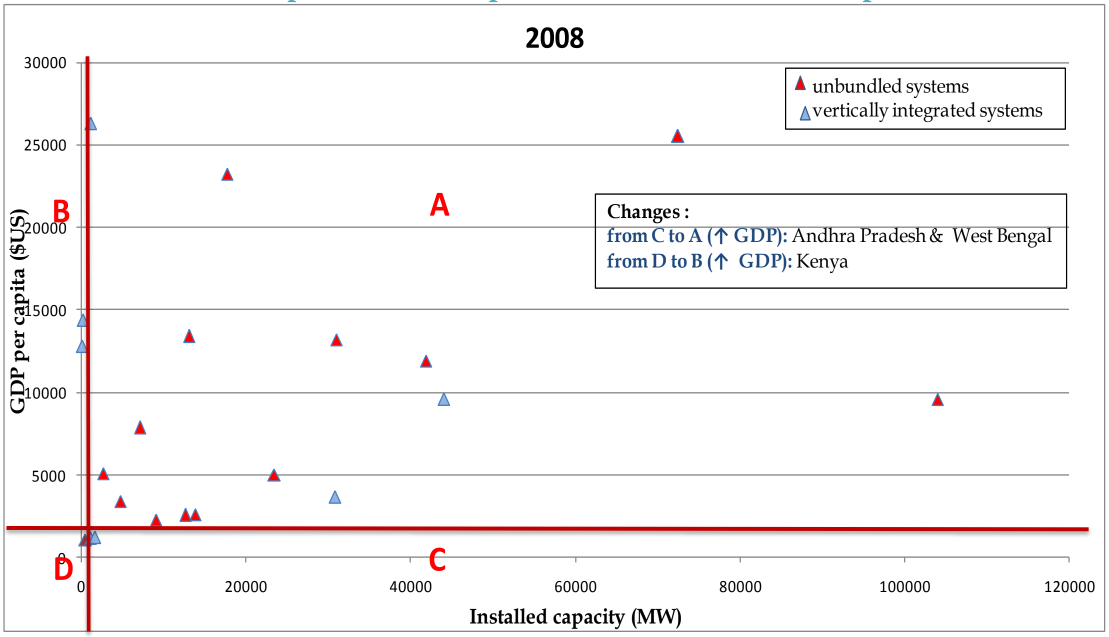
The starting time for our samples sees only two Latin American countries (Chile and Brazil) in Group A presenting some form of unbundling. By 1998, five countries in Group A, more than 40% of the sample for this group implemented unbundling off the system.

Figure 7
Scattered plot of the sample of countries in the intermediate period



Note: To separate the countries into different groups a threshold of 1178.5 MW for installed capacity, and $1429 for GDP per capita were applied. These thresholds represent for Group D approximately the lowest 25 percent of capacity and income of the sample.

Figure 8
Scattered plot of the sample of countries in the final period



Note: To separate the countries into different groups a threshold of 1178.5 MW for installed capacity, and $1429 for GDP per capita were applied. These thresholds represent for Group D approximately the lowest 25 percent of capacity and income of the sample.

Cautionary note

In cases where power sector restructuring was accompanied by a competitive power market, the results will show the combined impact of the two policy reforms. It may not be always easy to disentangle which results were caused only by restructuring, and which by competition. Similarly, in those cases where restructuring was accompanied by privatization, the impact in performance may differ from systems that adopted a comparable sector structure but did not introduce private sector participation. The assessment of the different "mix of conditions" for the same (or very similar) sector structure and system size may not always be possible, but the work will try to overcome such a challenge, if not through the case study approach then, through the systematic analysis, subject to data availability (see Zhang *et al.*, 2004 and 2008 who found the joint impact of restructuring with privatization and/or regulation stronger than the individual impact in terms of performance).

In what follows we report the evidence from i) empirical evidence of how performance indicators evolved over time and derivation of the links between unbundling and sectoral reforms on the one hand and performance indicators on the other hand ii) the case studies for the taxonomy of countries, reporting the timeline of reforms and the achieved results according to the set of chosen performance indicators.

4. Analytical approach

4.1 Data and definition of Indicators

Our data set is based on a panel of 22 countries for a period beginning in 1989 and extending through 2009. Since our panel dataset includes data on 22 countries for 20 years, the total number of maximum observations is 440.

The outcomes used for our econometric as well as our case study analysis are the four indicators of power sector performance listed in Table 2 that are used to measure the determinants of power sector performance, namely residential access to electricity, energy sold per employee of electricity suppliers as an indicator of labour productivity, average electricity tariff level as an indicator of financial efficiency, and the index of carbon dioxide emissions as an indicator of environmental sustainability.

Table 2
Selected Power Sector Performance Indicators

Variables	Definition
ACCESS	
Residential access (%population)	= number of residential connections divided by the total population
OPERATIONAL EFFICIENCY	
Energy sold per employee (MWh per employee)	= Amount of generated consumed from the interconnected system divided by the number of employees of the power supply entities for the whole power market (MWh per employee)
FINANCIAL EFFICIENCY	
Tariff level (US$c per KWh)	= average tariff (US$c per KWh)
ENVIRONMENTAL SUSTAINABILITY	
Carbon Emission Index (CO2 ton/Kwh)	= energy generated from each energy source weighted with the following coefficients of CO2 emission intensity by weight per unit of electricity generated divided by total amount of energy generated (coal = 1.00; petroleum fuels = 0.94; natural gas = 0.63; renewable energy and nuclear power = zero)

Appendix 2 reports the full list of variables collected in our database. Additional performance indicators, which have been included are indicators of quality (such as SAIDI and SAIFI), operational efficiency (such as capacity utilization, load factor), financial efficiency (such as cost recovery index), and long run environmentally sustainability indicators (such as the share renewables) and energy endowment (such as reserve capacity, and self-sufficiency).

Tables 3 and 4 reports the explanatory variables that our model will use to determine the power sector performance. Table 3 includes a comprehensive list of policy variables, such as the degree of vertical unbundling together with the degree of concentration and private sector participation of each segment of the market, as well as the introduction of an autonomous regulator.

Table 3
Explanatory Sectoral Policy Variables Influencing Power Sector Performance
(Expected Relationship)

Variables	Definition	Expected Sign	
		Performance indicators	Environmental indicators
DEGREE OF VERTICAL UNBUNDLING			
Partial Vertical Unbundling	= 1 from the year of separation of generation from transmission and distribution = 0 otherwise	+	-
Full Vertical Unbundling	= 1 from the year of separation of transmission from generation and distribution = 0 otherwise	+	-
DEGREE OF DISAGGREGATION			
Degree of disaggregation	= the reverse of the Hirschman-Herfindal index (HHI), computed separately for the generation, transmission, and distribution segments; in the case of generation is expressed in installed generating capacity (MW); in the case of transmission expressed in terms of km line length without discrimination between transmission voltage levels; in the case of distribution expressed in terms of total retail sales (MWh)	+	-
DEGREE OF PRIVATE SECTOR PARTICIPATION			
Share of private sector participation	= the percentage of private sector participation expressed in installed generating capacity (MW) in the generation segment; expressed in terms of km line length in the transmission segment; and expressed in terms of total retail sales (MWh) in the distribution segment	+	-
REGULATION			
Introduction of a regulatory agency	= 1 from the year of establishment of a regulatory agency = 0 otherwise	+	+

Table 4 introduces the key control variables related to GDP per capita and power system size, with a particular attention to Group A and Group D, the interaction between the groups with the policy variables, as well as additional indicators, including the financial crisis for Latin America, capital investment, and the share of fossil fuels in generation.

Table 4
Other Explanatory Variables Influencing Power Sector Performance
(Expected Relationship)

Variables	Definition	Expected Sign	
		Performance indicators	Environmental indicators
BASIC CONTROLS			
GDP per capita	= GDP per capita, PPP (constant 2005 international $)	+	+
Installed capacity (MW)	= Total installed capacity in the power system (MW)	+	-
POWER SYSTEM SIZE GROUP CONTROLS			
Group A	= 1 if above the threshold GDP per capita and installed capacity (determined by the lowest 25 percent of capacity and income of the sample) = 0 otherwise	+	+
Group D	= 1 if below the threshold GDP per capita and installed capacity (determined by the lowest 25 percent of capacity and income of the sample) = 0 otherwise	-	-
Group A*sectoral reforms	= Interacted variable between Group A and each of the sectoral reforms (competition, privatization and regulation)	+	-
OTHER CONTROLS			
Financial Crisis	= 1 for the 5 years after 2001 = 0 otherwise	-	
Share of fossil fuels (% installed capacity)	= Percentage of the total installed capacity in fossil fuels (oil, coal and natural gas	?	
Investment (US$/MWh)	= Capital expenditure per unit of energy generated (MWh)	+	
REGIONAL CONTROL			
Region *d_region1, 2, 3,4,5,6*	Dummies , 1=EAP, 2=ECA, 3=LAC, 4=MNA, 5=SAR, 6=SSA		

4.2 Theoretical hypotheses to be tested

Hypothesis 1 *Sectoral Reforms and Performance and traditional and environmental power sector performance*

The implementation of key sectoral reforms, including vertical and horizontal unbundling, privatization and regulation, is expected to be significantly associated with higher access and better operational and financial performance of the power sector. Such reforms may however be associated with environmentally non sustainable outcomes.

Some reforms (e.g. unbundling, wholesale competition) while expected to improve all indicators of technical and financial performance, may under some circumstances tend to discourage low carbon options. The arguments put forward are that integrated firms can coordinate the development of the network to accommodate renewable generations and a "single buyer" model allows policy makers to choose a mix of low carbon generators in a centralized and smoother way. The great advantage of a more competitive structure (compared to a vertically integrated one), for instance, is that new entrants can spot opportunities that incumbents have not exploited and is generally more conducive to better investment decision and innovative outcomes. Ultimately, which of the two effects will prevail is an empirical questions but one would presume that overall the former effects would dominate the latter.

Hypotheses 2A Differential impact of reforms depending on power system size and per capita income

Key sectoral reforms, particularly vertical and horizontal unbundling, are expected to produce the most significant results in the group of countries characterized by high power system size and income per capita. Such reforms are also likely to be associated with environmentally sustainable results for the same category of countries.

Hypotheses 2D Differential impact of reforms depending on power system size and per capita income

Key sectoral reforms, particularly vertical and horizontal unbundling, are not expected to be effective in the group of countries characterized by low power system size and income per capita. Such reforms are also likely to be associated with environmentally unsustainable results for the same category of countries

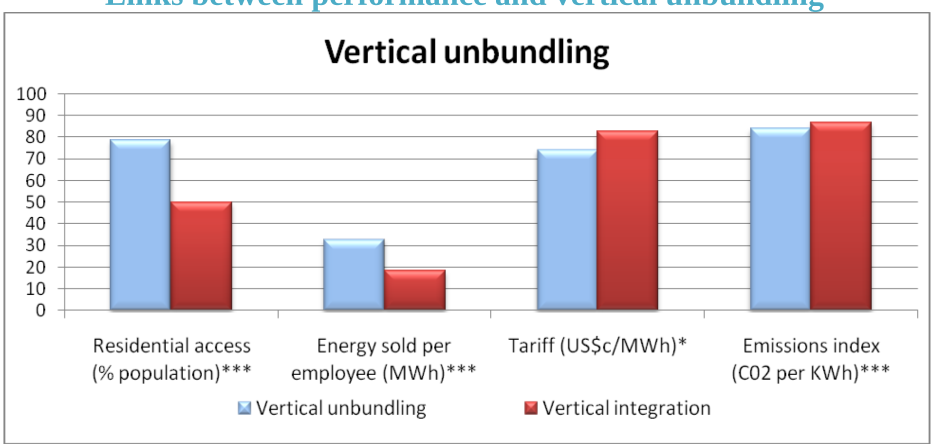
5. *Testing the hypotheses looking at the difference between sample means*

To get an initial indication from the data of whether the hypotheses we moved forward are confirmed, we can calculate the two means between different groups (e.g. the proportion of investment for the observations where vertical unbundling has been introduced) and compare them to see if one is greater than the other, and by how much. The significance of differences between two sample means can be assessed using the t-statistic calculated as part of the t-test. The t-statistic may be thought of as a scaled difference between the two means, where the absolute difference between means is rescaled using an estimate of the variability of the means. Such tests will be performed for each of the hypotheses.

5.1 *Testing Hypothesis 1*

Vertical unbundling is positively and significantly associated with better performance. Access and labor productivity are respectively 60 and 80% higher for systems that have introduced some form of vertical unbundling. Tariffs and CO2 emissions are lower by 10 and 5% respectively, indicating a higher degree of competitiveness and environmental sustainability (see Figure 9).

Figure 9
Links between performance and vertical unbundling

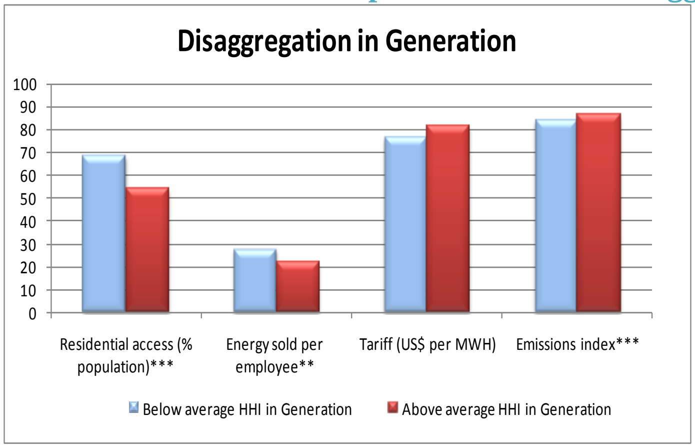


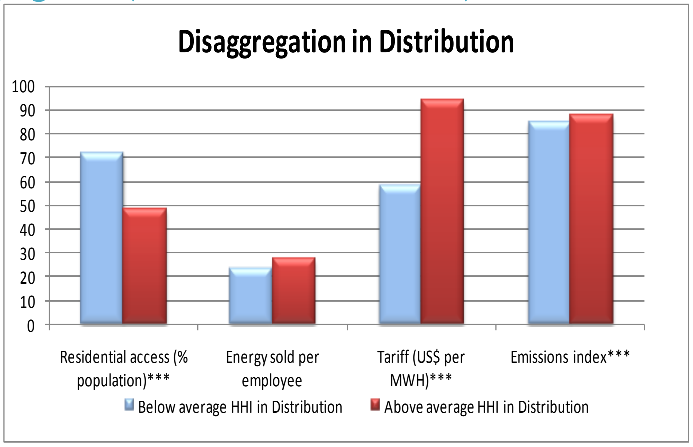
	Vertical unbundling	Vertical integration	t
Residential access (% population)* **	78.2 (27.7)	49.7 (33.9)	-8.7
Energy sold per employee* **	32.8 (27.89)	18.3 (17.03)	-4.9
**Tariff (US$ per MWH)* **	74.0 (32.8)	53.4 (60.1)	1.5
Emissions index* **	83.7 (6.4)	86.8 (9.3)	3.5

Note: The following adjustments were made to make the indicators fit in the same figure. Tariff ($US cent per MWh) and Emissions index (that is measured as a number from 0 to 1) were multiplied by 100. Energy sold per employee (measured in MWh per employee) was divided by 100. *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

Disaggregation in generation is also positively and significantly associated with better performance, even if to a lower extent than vertical unbundling. Access and labor productivity are about 20% higher for systems that have reduced concentration in the generation segment of the market. Tariffs and CO2 emissions are lower by 5 and 2% respectively, indicating a higher degree of competitiveness and environmental sustainability (see Figure 10a).

Figure 10
Links between performance and disaggregation (inverse of concentration)





	Below average HHI in Generation	Above average HHI in Generation	t
Residential access (% population)***	68.3 (35.2)	53.9 (32.5)	3.6
Energy sold per employee	27.7 (26.96)	22.2 (19.79)	1.7
Tariff (US$ per MWH)***	76.5 (28.4)	81.4 (60.1)	-0.8
Emissions index***	84.1 (5.9)	86.2 (10.1)	-2.1

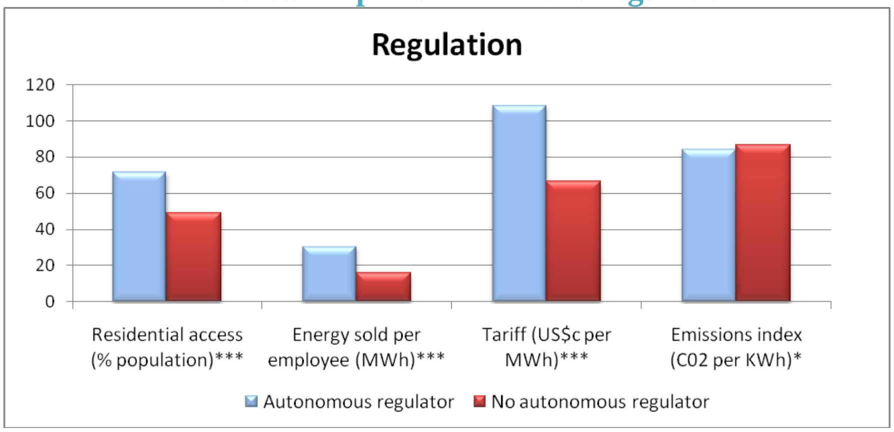
	Below average HHI in Distribution	Above average HHI in Distribution	t
Residential access (% population)***	71.9 (28.5)	48.3 (36.3)	5.6
Energy sold per employee	23.4 (13.5)	25.5 (28.5)	-1.2
Tariff (US$ per MWH)***	58.2 (29.3)	94.2 (49.1)	-5.8
Emissions index***	84.8 (3.9)	87.9 (8.2)	-3.6

Note: The following adjustments were made to make the indicators fit in the same figure. Tariff ($US cent per MWh) and Emissions index (that is measured as a number from 0 to 1) were multiplied by 100. Energy sold per employee (measured in MWh per employee) was divided by 100. *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

Disaggregation in distribution is also generally positively and significantly associated with better performance, with the exception of labor productivity. Access is 50% higher for systems that have reduced concentration in the distribution segment of the market. Labor productivity is slightly lower but not significantly so. Tariffs and CO2 emissions are lower by 40 and 5% respectively, indicating a higher degree of competitiveness and environmental sustainability (see Figure 10b).

The introduction of an autonomous regulator is positively and significantly associated with better performance. Access and labor productivity are respectively 50 higher and twice as high for systems that have introduced regulation. Tariffs are higher, indicating a stronger commitment to make tariff more cost reflective. Finally, higher environmental sustainability is reached, with CO2 emissions are lower by 3% (see Figure 11).

Figure 11
Links between performance and regulation

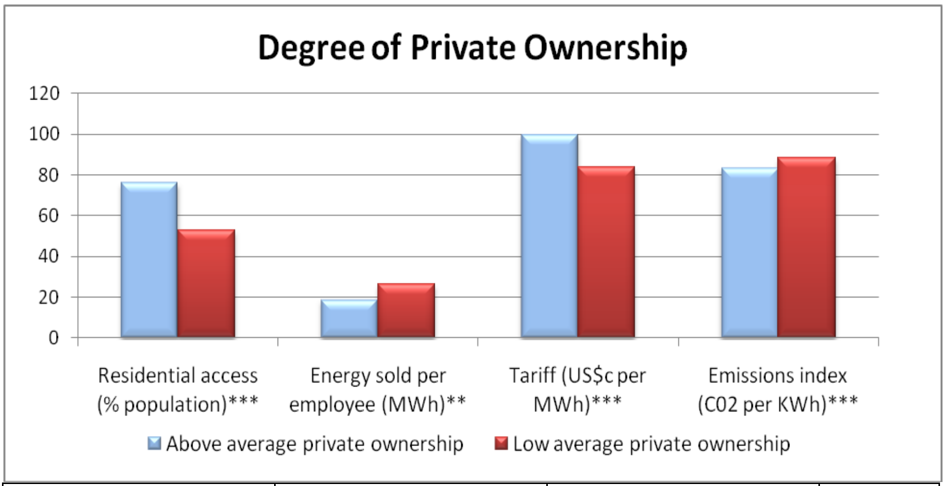


	Autonomous regulator	No autonomous regulator	t
Residential access (% population)* **	72.1 (30.6)	48.9 (34.8)	-6.7
Energy sold per employee* **	30.9 (25.1)	15.8 (17.8)	-5.1
Tariff (US$ per MWH)* **	108.7 (111.5)	66.4 (27.1)	-3.5
Emissions index*	84.5 (8.4)	86.7 (8.4)	2.5

Note: The following adjustments were made to make the indicators fit in the same figure. Tariff ($US cent per MWh) and Emissions index (that is measured as a number from 0 to 1) were multiplied by 100. Energy sold per employee (measured in MWh per employee) was divided by 100. *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

The introduction of private sector participation shows a similar trend to that for regulation, with the exception of labor productivity. Access is about 40% higher for systems that have introduced private participation. Labor productivity is 30% lower. Tariffs are 20% higher, reflecting the need to make tariff more cost reflective in order to attract the private sector. Finally, higher environmental sustainability is reached, with CO2 emissions are lower by 5% (see Figure 12).

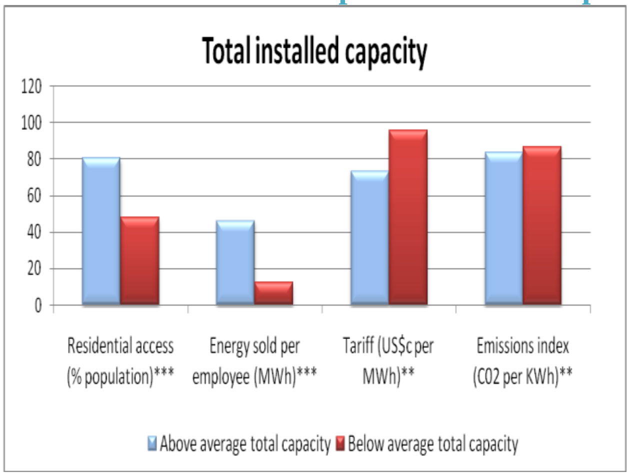
Figure 12
Links between performance and privatization

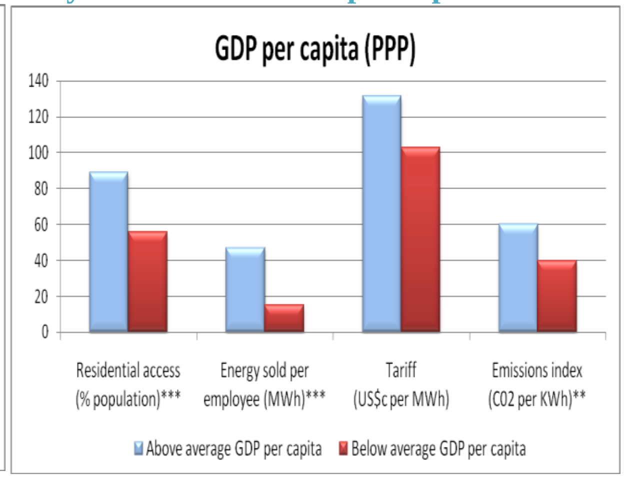


	Above average private ownership	Below average private ownership	t
Residential access (% population)* **	76.1 (30.9)	52.6 (35.1)	-4.7
Energy sold per employee* *	18.7 (11.9)	26.3 (28.3)	1.8
Tariff (US$ per MWH)* **	99.8 (52.3)	83.7 (40.3)	-2.2
Emissions index* **	83.4 (7.7)	88.3 (4.9)	5.0

Note: The following adjustments were made to make the indicators fit in the same figure. Tariff ($US cent per MWh) and Emissions index (that is measured as a number from 0 to 1) were multiplied by 100. Energy sold per employee (measured in MWh per employee) was divided by 100. *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

Figure 13
Links between performance and power system size and GDP per capita





	Above average total capacity	Below average total capacity	t
Residential access (% population)* **	80.7 (18.8)	48.1 (36.4)	-9.2
Energy sold per employee* **	46.5 (23.8)	12.3 (9.6)	-15.3
Tariff (US$ per MWH) **	73.8 (42.8)	95.9 (93.5)	2.0
Emissions index **	83.9 (9.8)	86.6 (7.5)	2.9

	Above average GDP per capita	Below average GDP per capita	t
Residential access (% population)* **	83.1 (1.5)	42.1 (2.5)	-13.9
Energy sold per employee* **	40.4 (25.2)	11.5 (9.1)	-11.3
Tariff (US$ per MWH)	97.0 (50.9)	90.7 (118.2)	-7.4
Emissions index **	88.3 (8.9)	83.2 (7.1)	-6.2

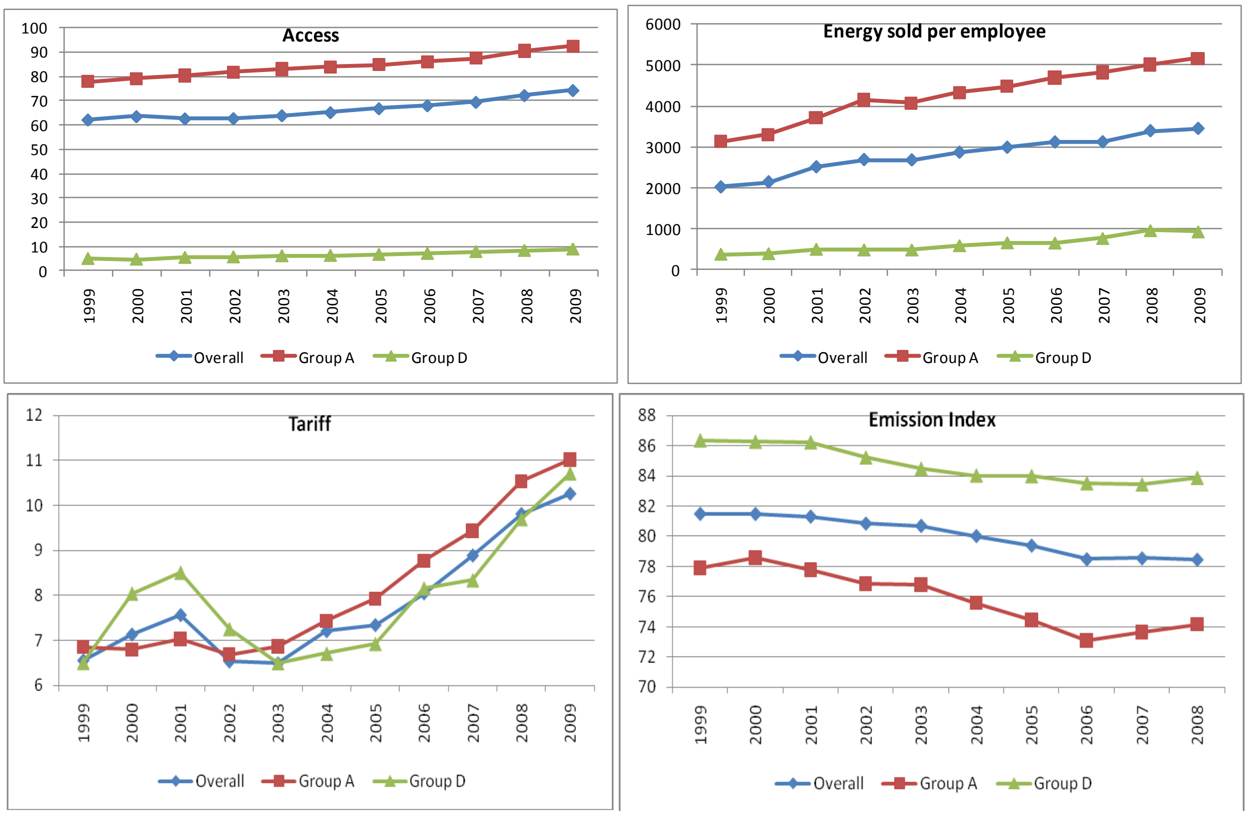
Note: The following adjustments were made to make the indicators fit in the same figure. Installed capacity (measured in MW), and GDP per capita (measured in $US) were divided by 100. *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

Countries characterized by higher power system installed capacity are characterized by significantly better performance than countries with lower installed capacity. Access and labor productivity are respectively 70% and 4 times higher for above average power systems. Tariffs and CO2 emissions are lower by 25 and 3% respectively, indicating a higher degree of competitiveness and environmental sustainability (see Figure 13a). Finally, countries characterized by higher GDP per capita are characterized by significantly better performance than countries with lower GDP per capita. Access and labor productivity are respectively 60% and 3 times higher for above average income. Tariffs and CO2 emissions are 30% and 50% higher, indicating that utilities are able to charge more cost oriented tariff but the higher generation is reflected in higher pollution (see Figure 13b).

5.2 Testing Hypothesis 2

Figure 14 compares the average performance levels of all the selected countries as a group with the average levels for the country Groups A and D over the ten-year period 1999 to 2009 in terms of the four main performance indicators: access, energy sold per employee, tariff, and emission index. Group A countries consistently outperform Group D countries on all indicators. Yet the trends for all performance indicators are rising – improving – for all country groups over this period.

Figure 14
Power Sector Performance Indicators over Time

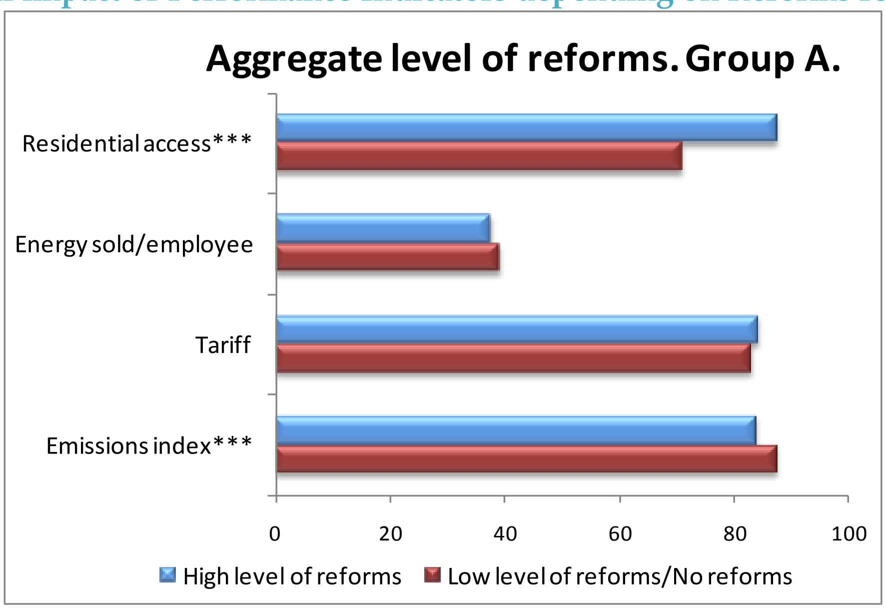


Testing Hypothesis 2A & 2D

To get an initial indication from the data of whether hypotheses 2A and 2D are confirmed, we can calculate the two means within Group A and D of countries that have implemented unbundling together with other reforms (reduction in market concentration, introduction of an autonomous regulator, and introduction of private ownership) and others that have not done so and compare them to see if the level of access, labour productivity, tariffs, and emissions is greater than the other, and by how much. The significance of differences between two sample means can be assessed using the t-statistic calculated as part of the t-test. The t-statistic may be thought of as a scaled difference between the two means, where the absolute difference between means is rescaled using an estimate of the variability of the means. Such tests will be performed for each of the hypotheses. Appendix 3 report the results of the t-test for all the variables collected in the database.

The results of t-tests for group A are presented in Figure 15 for our selected variables for which we run the econometric model. The results show that high level of reforms is associated with higher residential access and lower emissions index. Labour productivity and tariffs do not appear to vary with the level of reforms.

Figure 15
Differential impact of Performance Indicators depending on Reforms for Group A

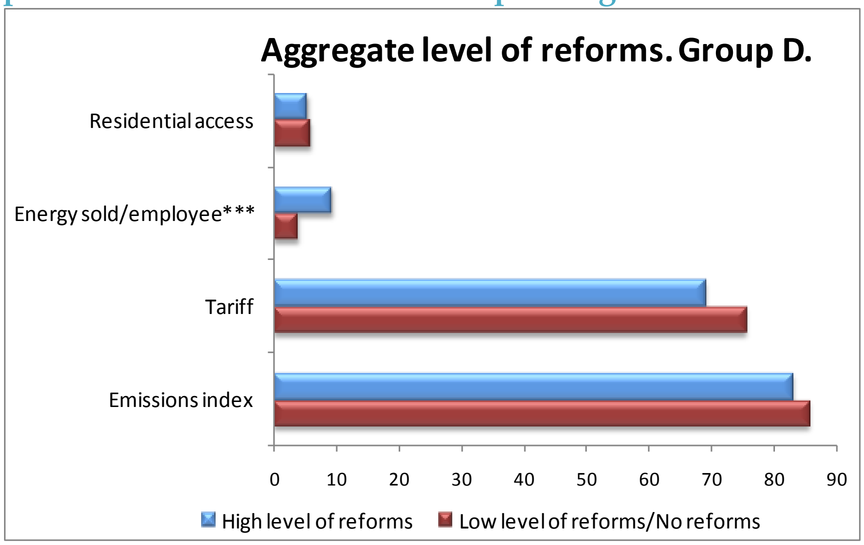


	High level of reforms	Low level of reforms/No reforms	t
Residential access (% population)* **	87.5 (10.7)	70.9 (19.6)	-5.9
Energy sold per employee	37.7 (32.2)	39.2 (20.9)	.3
Tariff (US$ per MWH)	84.2 (23.3)	83.0 (48.1)	-.2
Emissions index* **	83.9 (5.3)	87.5 (8.7)	2.9

Note: The following adjustments were made to make the indicators fit in the same figure. Tariff ($US cent per MWh) instead. Emissions index (that is measured as a number from 0 to 1) was multiplied by 100. Energy sold per employee (measured in MWh per employee), Installed capacity (measured in MW), and GDP per capita (measured in $US) were divided by 100. *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

The same exercise was conducted for group D. The results presented in Figure 16 show that while there are no significant differences between the level of residential access, the level of emissions index, and tariff between two groups, there is significant difference in the levels of labour productivity. Higher level of reforms is associated with significantly higher labour productivity.

Figure 16
Differential impact of Performance Indicators depending on Reforms for Group D



	High level of reforms	Low level of reforms/No reforms	t
Residential access (% population)	5.5 (3.2)	5.9 (2.5)	.4
Energy sold per employee* **	9.36 (2.56)	3.94 (1.47)	-8.2
Tariff (US$ per MWH)	69.1 (5.7)	75.6 (2.2)	.5
Emissions index	83.1 (.7)	85.7 (6.8)	1.0

Note: The following adjustments were made to make the indicators fit in the same figure. Tariff ($US cent per MWh and the Emissions index (that is measured as a number from 0 to 1) were multiplied by 100. Energy sold per employee (measured in MWh per employee) was divided by 100. *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

6 *Regression Results*

The basic regression model reports the results of the links of unbundling and other sectoral reforms including reduction of concentration in generation and distribution, regulation and introduction of private sector participation in the different segments of the market (reported in table 5) on performance. It also controls for power system size and income and their interactions. Finally more specifically additional explanatory variables are introduced (as reported in table 6).

Tables 5 and 6 below present estimation results for the fixed and random effect models. The preferred specifications vary depending on the independent variables, as shown in Table 7 where the results of Hausman and BPLM tests and the preferred specifications based on these tests are reported.

6.1 Results of testing Hypothesis 1

As the results reported in Tables 5 and 6 show, Hypothesis 1 is generally confirmed across the board of all indicators, reflecting the positive impact of unbundling and sectoral reforms on performance. There are however, nuances across the impact of unbundling and sectoral reforms on the different performance indicators that are reported below.

i Access

The level of access is positively linked to full vertical unbundling, even if not significantly so. Partial unbundling is negatively and significantly associated with lower levels of access. It is positively and significantly linked to the increase of disaggregation in generation. This result can be interpreted noting that developing countries have been able to scale up access after attracting more players and investment in generation, so as to add needed installed capacity and/or through entry of distributed generation and the appropriate combination of grid and off-grid generation supply. The source of power generation that is positively though not significantly associated with enhanced access is fossil fuels generation.

Among the forms of competition in generation the introduction of private sector participation in generation also is significantly linked to access expansions, proving that IPPs and divestiture of formerly state-owned generators can deliver positive results. Independent power producers (IPPs) are an important catalyst in the electricity sector reform as they are often the first private investors in a power market dominated by state-owned power utilities. With entry of a sufficient number of IPPs in the market, supply grew and access has been scaled up.

The introduction of an autonomous regulator is also significantly positively associated with higher access, confirming that regulators can also play an important role in ensuring that contracts were effectively designed. IPPs sold their generated electricity to state-owned utilities, which entered into long term power purchasing agreements (PPAs) with state-backed guarantees for the off-taking utility's performance. By signing long term PPAs, IPPs accepted construction and operating risks and shared fuel availability risk with fuel suppliers. In most cases, they were protected from demand risk under the terms of their PPAs for their debt servicing needs and equity returns.

Table 5
Regression Results of determinants of Power Sector Performance (Fixed Effects)

FIXED EFFECTS	Residential Access (%)	Energy sold (MWh/employee)	Tariff (US$c/KWh)	Emission index (CO_2 ton/KWh)
DEGREE OF UNBUNDLING				
Partial unbundling	-2.72* (1.43)	-542.94*** (192.53)	-0.46 (1.82)	0.02*** (0.01)
Full unbundling	0.18 (1.36)	-208.36* (118.09)	1.98*** (0.82)	0.004 (0.009)
DEGREE OF DISAGGREGATION				
HHI generation (reverse)	0.0008** (0.0003)			-0.00001*** (0.0000002)
HHI distribution (reverse)		0.63 (0.40)	-0.006*** (0.002)	
DEGREE OF PRIVATE OWNERSHIP				
Privatization in Generation (dummy)	3.46*** (1.16)			0.02*** (0.008)
Privatization in Distribution/Total (share)		9.57*** (3.47)	0.37** (0.17)	
REGULATION				
Introduction of an autonomous regulator	3.94*** (0.96)	299.34*** (88.19)	2.32*** (0.79)	-0.025*** (0.007)
CONTROLS				
GDP per capita (thousand US$)	3.7*** (0.4)	190*** (44.)	2.*** (0.2)	0.0003 (0.002)
Installed capacity (MW thousand)	0.6*** (0.08)	169*** (16.6)	0.303*** (0.067)	- 0.003** (0.001)
GDP per capita* Installed capacity	-0.047*** (0.005)	-3.38*** (0.65)	-0.019*** (0.003)	0.0001 (0.00004)
Financial crisis			-0.87*** (0.32)	
Capex (US$/MWh)			0.28*** (0.11)	
Share of fossil fuels (access)/hydro (emission) (% installed capacity)	0.10 (0.07)			-0.0007* (0.0004)
Constant	21.68*** (5.62)	3845.99 (3453.8)	-60.63*** (17.76)	0.79*** (0.03)
N	271	166	129	318
F	61.29***	223.77***	14.80***	8.95***
Within R^2	0.64	0.90	0.53	0.23
Between R^2	0.40	0.46	0.53	0.09
Overall R^2	0.49	0.61	0.41	0.03

*Note: *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.*

Table 6
Regression Results of determinants of Power Sector Performance (Random Effects)

RANDOM EFFECTS	**Residential Access (%)**	**Energy sold (MWh/employee)**	**Tariff (US$c/KWh)**	**Emission index (CO2 ton/KWh)**
DEGREE OF UNBUNDLING				
Partial Unbundling	-2.24 (1.42)	-492.28*** (189.52)	-0.15 (1.82)	0.02** (0.01)
Full Unbundling	0.38 (1.3)	-188.37* (112.19)	1.58* (.93)	0.007 (0.009)
DEGREE OF DISAGGREGATION				
HHI in generation (reverse)	0.0008*** (0.0003)			0.00001*** (0.0000003)
HHI in distribution (reverse)		0.24* (0.13)	- 0.001*** (0.0002)	
REGULATION				
Introduction of an autonomous regulator	4.56*** (0.91)	266.74*** (87.69)	4.02*** (0.85)	0.026*** (0.01)
DEGREE OF PRIVATIZATION				
Privatization (as per previous table)	3.52*** (1.16)	9.29*** (3.39)	0.04* (0.023)	0.02** (0.008)
MACROECONOMIC CONTROL				
GDP per capita (US$ thousands)	3.*** (0.3)	180*** (37.)	0.3*** (0.1)	0.003 (0.002)
Financial crisis			-1.02*** (0.39)	
SECTORAL CONTROL				
Installed capacity (MW thousands)	0.6*** (0.07)	180*** (16.0)	0.1*** (0.04)	-0.001* (0.0006)
GDP per capita* Installed capacity	-0.004*** (0.005)	-2.93*** (0.612)	-0.007*** (0.003)	-0.0001*** (0.00003)
Capex (US$/MWh)			0.25*** (0.13)	
Share of fossil fuels/hydro (% installed capacity)	0.072 (0.05)			-0.0005* (0.0003)
REGIONAL CONTROLS				
Regional dummies	Yes	Yes	Yes	Yes
Constant	45.15*** (5.27)	-170.18 (1110.83)	-7.81*** (2.34)	0.81* (0.36)
N	271	166	129	318
Wald $\chi 2$	650.78***	1416.05***	108.37***	
Within R^2	0. 64	0.90	0.33	0.22
Between R^2	0.92	0.76	0.69	0.29
Overall R^2	0.92	0.81	0.63	0.35

Note: *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

TABLE 7
FIXED AND RANDOM EFFECT TESTS

	Access	Operational Efficiency	Financial Efficiency	Emissions Index
HAUSMAN TEST FOR FIXED EFFECT				
Hausman $\chi 2$ (8)	7.55	17.49***	98.75***	7.39
PREFERRED SPECIFICATION				
Fixed effect	✓	✗	✗	✓
Random effect	✗	✓	✓	✗
BREUSCH AND PAGAN LAGRANGIAN MULTIPLIER TEST				
BPLM $\chi 2$ (1)		323.91***	31.91***	
PREFERRED SPECIFICATION				
Random effect		✓	✓	
Pooled		✗	✗	

Finally as expected higher income countries are characterized by significantly higher levels of access, as is the case for countries with larger system size. The interacted term between GDP per capita and power system size is negative, revealing decreasing returns to scale by the highest income countries - such as OECD countries - which have already achieved close to universal access and face an exponentially increasing cost in connecting each new consumer as they approach full coverage. The explanatory power of these variables is very high, reaching 90% in the preferred specification of random effects.

ii. Labor productivity:

The level of labor productivity (expressed in terms of energy sold per employee) is significantly reduced by both partial and full vertical unbundling. It is instead enhanced by the increase of disaggregation in distribution. More players in distribution are expected to drive efficiency gains through means such as benchmark competition (also known as yardstick competition).

The introduction of private sector participation also helped to significantly enhance operational efficiency and labor productivity in distribution.

The presence of autonomous regulator has also significantly contributed to higher labor productivity, most likely by creating a more even playing field to attract private participation in distribution.

Finally as expected higher income countries are characterized by significantly higher levels of labor productivity, as are also countries with larger system sizes. The interacted term between GDP per capita and power system size is also in this case negative, revealing decreasing returns to scale for the highest income countries with larger power systems and which have already achieved high levels of labor productivity.

This specification has a very strong explanatory power with a level for R2 of more than 80% for the preferred random effect specification.

iii. Tariffs

Full unbundling in line with the finding of earlier literature including Steiner (2001) significantly enhanced the level of tariffs, whereas partial unbundling has no significant impact on tariffs. On the other hand, more disaggregation in distribution drives electricity tariffs down, most likely as a result of yardstick competition and less collusion between players in the market. An earlier study by Steiner (2001) of 19 OECD countries for the period 1986-1996 found instead that unbundling was not associated with lower prices, but is associated with a lower industrial to residential price ratio.

In this case however, a higher share of private sector participation significantly raises the level of tariffs, most likely reflecting the need to raise tariffs to attract private participation in distribution.

The presence of an autonomous regulator is also significantly and positively associated with higher tariffs, reflecting the need to insulate crucial decisions related to pricing from political interferences.

As expected, higher income countries are characterized by significantly higher levels of prices, as are also countries with larger system sizes. The interacted term between GDP per capita and power system size is once again negative, revealing decreasing returns to scale in the highest income countries which have already achieved high levels of tariffs.

Some cautionary remarks are needed. A more accurate indicator of financial efficiency would be provided by the degree of cost recovery. However, the much smaller number of observations available for such an indicator made a rigorous approach (through panel analysis not possible. Accordingly, additional regressions were performed, controlling for the level of costs and energy endowment. As shown in Table 5, higher investment in the power sector is also significantly associated with higher tariffs, reflecting the fact that capital expenditure is partially financed by the tariff and passed through to consumers. Short run shocks including financial crises are significantly and negatively associated with tariffs, reflecting the challenges of keeping prices at cost reflective levels in periods when consumer protection takes priority.[1]

iv. Carbon emission index

Partial and vertical unbundling is associated with higher carbon emissions, but only partial unbundling significantly so. Higher competition in generation is also significantly associated with higher sustainable environmental outcomes, reducing the carbon emissions from fossil fuels. A possible interpretation is that integrated firms can coordinate the development of the network to accommodate renewable generation sources and a "single buyer" model allows

[1] Other variables (including the sources of energy from which electricity is generated) do not indicate the presence of a relation with the tariff level. In order to keep the model parsimonious the coefficient is not included into the specification presented in Table 5. All other coefficients including the policy variables are not affected from the inclusion of this parameter into the specification.

policy makers to ensure that a mix of low carbon generators is incorporated into the centralized dispatch of generation capacity to meet demand on the power system without compromising supply reliability.

Private ownership in generation is also significantly and positively associated with less environmental sustainable outcomes, raising the carbon emissions from burning fossil fuels.

The presence of an autonomous regulator is also significantly associated with higher carbon emissions, proving that environmental considerations have a relatively lower priority compared to the traditional functions of energy policy and regulation, such as to protect consumers from high prices and ensure that power firms will be able to recoup their investment. These goals can be sometimes conflicting with each other. Improved access to reliable, secure, affordable, energy represent a much higher priority particularly in countries characterized by low levels of income.

As expected, higher income countries are characterized by significantly higher levels of carbon emissions. However, countries with larger system sizes are significantly associated with lower levels of carbon emissions, most likely due to the presence of economies of scale and the fact that smaller and isolated systems are in many cases mostly dependent on oil imports and find it more difficult to diversify sources of energy. The interacted term between GDP per capita and power system size is not significant.

6.2 Results of testing Hypothesis 2A

As the results reported in Table 9 show, Hypothesis 2A postulating the greatest effectiveness and impact of unbundling and reforms for countries in Group A, characterized by large power system and higher GDP per capita, is generally confirmed across the board of all performance indicators, reflecting the positive impact of unbundling and sectoral reforms on performance. There are however, nuances across the impact of unbundling and sectoral reforms on the different performance indicators that are reported below.

To undertake this task for each of the regressions reported in Table 5, we introduce interaction variables which allow us to explore the synergistic effects of the combined predictors. The interaction variables are created by multiplying each of the selected reform variables with Group A. For instance, in the case of unbundling the interacted variable is given by the product between (either partial or full) unbundling and Group A of countries, capturing the differential impact of unbundling in the group of countries characterized by large system size and high income per capita.

Differential impact of vertical unbundling in Group A

- Vertical unbundling (in both specifications, namely either partial or full or full only) when interacted with Group A countries is significantly associated with enhanced access and more sustainable levels of CO2 emission generated by fossil fuels, reflecting both economic and environmental benefits to power users, due to increased efficiency of use of fossil fuels.
- There is, however, no significant link with operational or financial efficiency. This implies that for this group of countries the high prevailing level of labour productivity offers decreasing returns to scale. It should also be noted that unbundling per se did not have any significant impact on labor productivity in the overall sample (see Table 5). In

the case of financial efficiency, instead, the overall link between vertical unbundling and tariff was positive and significant, reflecting the fact that the costs of unbundling were passed through to consumers.

Differential impact of disaggregation in Group A

- Similarly to vertical unbundling, higher disaggregation of the generation segment of the market when interacted with group A is significantly associated with enhanced access and more sustainable levels of CO2 emission generated by fossil fuels, reflecting the benefits to the users as well as to environment, due to increased efficiency of use of fossil fuels when more players are introduced.
- Reduction in the concentration of the distribution segment of the market for the countries belonging to Group A is positively and significant linked with enhanced operational efficiency, but there are no links with enhanced financial efficiency. This implies that for group of countries the already achieved in the level of tariff is already so high that there are decreasing returns to scale. It should also be noted that disaggregation of the distribution segment per se did not have a significant impact on labor productivity in the overall sample (see Table 5). Its effectiveness is found only for countries characterized by large system size and high GDP per capita. In the case of financial efficiency, instead, the overall link between distribution disaggregation and tariff was negative and significant, reflecting the fact that the beneficial impact of competition (or at least benchmarking) of additional distribution players on reducing costs and tariffs.

Differential impact of private sector participation in Group A

- The introduction of private sector participation in the generation segment of the market when interacted with Group A is not significantly associated with access or carbon emissions generated from fossil fuels. It should also be noted that higher degree of private sector participation per se did have a significant and positive impact by enhancing access but at the cost of adding carbon emissions (see Table 5). This implies that for countries belonging to Group A, the achieved level of access is already so high that privatization of generation is not sought to enhance connectivity. There is also no significant evidence of environmental unsustainability results brought by the private sector in generation, differently from the overall sample where higher private sector participation was associated with higher emission levels.
- The introduction of private sector participation in the distribution segment of the market for the countries belonging to Group A is positively and significant linked with enhanced operational efficiency, but there are no links with enhanced financial efficiency. It should also be noted that higher private sector participation in the distribution segment per se did also have a significant impact on labor productivity in the overall sample (see Table 5). In the case of financial efficiency, instead, the overall link between private sector participation in distribution and tariff was positive and significant, reflecting the fact that in order to attract the private sector more cost reflective tariffs were needed. This seems to imply that for Group A of countries the already achieved level of tariff is already found enough to attract private sector participation in distribution.

Table 9

Determinants of Power Sector Performance (Fixed Effects and interactions with Group A)

Interactions with Group A Fixed effects	Residential Access (%)	Energy sold (MWh/employee)	Tariff (US$c/KWh)	Emission index (CO2 ton/KWh)
DEGREE OF UNBUNDLING (EITHER PARTIAL OR FULL)				
Group A	9.13*** (1.99)	-61.05 (251.98)		0.01 (0.01)
Vertical Unbundling	-6.67*** (1.78)	47.97 (146.29)	2.51*** (0.92)	0.03** (0.01)
Group A*Vertical Unbundling	7.92*** (2.12)	-365.51 (230.38)	-1.36 (1.23)	-0.03** (0.02)
FULL VERTICAL UNBUNDLING				
Group A	9.71*** (1.96)	-186.01 (237.65)		0.03** (0.01)
Vertical Unbundling (full)	-6.75*** (1.83)	77.04 (136.79)	2.49*** (0.92)	0.03** (0.01)
Group A*Vertical Unbundling (full)	7.81*** (2.27)	-63.59 (222.99)		-0.08*** (0.02)
DEGREE OF DISAGGREGATION				
Group A	-29.18*** (5.96)	-2247.13** (48097.47)		0.15*** (0.41)
HHI (reverse)	-0.002*** (0.0006)	18*** (13.38)	-0.021 (.016)	0.00002*** (0.000004)
Group A* HHI (reverse)	0.002*** (0.0006)	0.66** (13.38)	0.019 (0.016)	-0.00002*** (0.000004)
DEGREE OF PRIVATIZATION				
Group A	12.27*** (2.40)	-702.76* (370.87)		0.09 (0.01)
Privatization	2.51* (1.59)	4.40 (3.51)	0.17 (0.27)	0.023*** (0.01)
Group A*Privatization	1.66 (2.18)	21.61** (9.14)	0.47 (0.38)	-0.009 (0.01)
REGULATION				
Group A	10.48*** (2.39)	-341.33 (283.82)		-0.0008 (0.01)
Introduction of a regulatory agency	3.06*** (1.12)	73.41 (120.71)	4.96*** (0.95)	0.04*** (0.01)
Group A*Regulatory Agency	5.9*** (1.65)	564.08*** (176.14)	-9.6*** (1.66)	-0.04*** (0.01)

'Note: *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

Differential impact of regulation in Group A

- The introduction of an autonomous regulator when interacted with Group A is significantly associated with enhanced access, higher operational efficiency, lower tariffs and more sustainable level of CO2 emission generated by fossil fuels, reflecting the benefits to the users, producers as well as to environment, due to increase efficiency of use of fossil fuels.

6.3 Results of testing Hypothesis 2D

As the results reported in Table 10 shows, Hypothesis 2D postulating the lower effectiveness and impact of unbundling and reforms for countries in Group A, characterized by large power system and higher GDP per capita is generally confirmed across the board of all indicators, reflecting the negative impact of unbundling and sectoral reforms on performance. There are however, nuances across the impact of unbundling and sectoral reforms on the different performance indicators that are reported below.

Also in this case for each of the regressions reported in Table 5, we introduce interaction variables created by multiplying each of the selected reform variables with Group D. For instance, in the case of unbundling the interacted variable is given by the product between (either partial or full) unbundling and Group D of countries, capturing the differential impact of unbundling in the group of countries characterized by small system size and low income per capita.

Differential impact of vertical unbundling in Group D

- Vertical unbundling (in both specifications, namely either partial or full or full only) when interacted with Group D is significantly associated with reduced access and less sustainable levels of CO2 emission generated from fossil fuels. Full vertical unbundling is also positively and significantly associated with higher level of tariffs, as found for the overall sample of countries.
- Vertical unbundling is, however, significantly linked with higher operational efficiency. This implies that for this group of countries the benefits of unbundling is only reflected through restructuring and laying off of redundant employees. It should also be noted that unbundling per se did not have any significant impact on labor productivity in the overall sample (see Table 5).

Differential impact of disaggregation in Group D

- Similarly to vertical unbundling, higher disaggregation of the generation segment of the market when interacted with Group D is significantly associated with reduced access, but in this case it is associated with more sustainable level of CO2 emission generated by fossil fuels.
- Reduction in the concentration of the distribution segment of the market for the countries belonging to Group D is negatively linked with operational and financial efficiency, but not significantly so.

Differential impact of private sector participation in Group D

- The introduction of private sector participation in the generation segment of the market when interacted with Group D is significantly associated with reduced level of access but is not significantly linked to the carbon emission generated by fossil fuels. It should also be noted that for the overall sample of countries higher degree of private sector participation per se did have a significant and positive impact by enhancing access but at the cost of adding carbon emissions (see Table 5).
- The introduction of private sector participation in the distribution segment of the market for the countries belonging to Group D is negatively and significantly linked with operational efficiency, but there are no links with enhanced financial efficiency. This result contrasts with the overall finding that higher private sector participation in the distribution segment per se did have a significant impact on labor productivity (see Table 5). In the case of financial efficiency, instead, the overall link between private sector participation in distribution and tariff was positive and significant, reflecting the fact that in order to attract the private sector more cost reflective tariffs were needed.

Differential impact of regulation in Group D

- The introduction of an autonomous regulator when interacted with Group D is significantly associated with reduced access, lower operational efficiency, higher tariffs, reflecting a lack of benefits to users and producers. It is however associated with more sustainable level of CO2 emission generated from fossil fuels, as well as to environment. This result underscores the challenges in implementing regulatory reforms in this group of countries.

Table 10
Determinants of Power Sector Performance (Fixed Effects and interactions with Group D)

Interactions with Group D Fixed effects	Residential Access (%)	Energy sold (MWh/employee)	Tariff (US$c/KWh)	Emission index (CO2 ton/KWh)
UNBUNDLING (EITHER PARTIAL OR FULL)				
Group D	8.76* (4.72)	-17.83 (468.29)	-0.22 (2.20)	-0.05* (0.04)
Vertical Unbundling	1.65 (1.13)	-336.29** (174.92)	1.14 (0.83)	0.003 (.009)
Group D*Vertical Unbundling	-8.74*** (2.04)	403.85* (222.61)	1.48 (1.25)	0.03** (0.01)
FULL VERTICAL UNBUNDLING				
Group D	9.76* (5.23)	207.63 (438.64)	-1.33 (2.05)	-0.08** (0.04)
Vertical unbundling (full)	3.04* (1.67)	-44.22 (174.55)		-0.03*** (0.01)
Group D*Vertical unbundling (full)	-9.47*** (2.37)	138.85* (214.28)	2.61*** (0.94)	0.06*** (0.02)
DEGREE OF DISAGGREGATION				
Group D	-29.18*** (5.96)	-2247.13** (48097.47)		0.15*** (0.41)
HHI (reverse)	0.0002 (0.0004)	0.88** (0.44)	-0.002 (0.002)	-0.000004* (0.000003)
Group D* HHI (reverse)	-0.002*** (0.0007)	-0.02 (0.04)	-0.0001 (0.0002)	-0.00002*** (0.000005)
DEGREE OF PRIVATIZATION				
Group D	8.03 (5.74)	515.03 (391.43)	1.32 (2.12)	-0.03 (0.04)
Privatization	4.08*** (1.36)	25.95*** (8.67)	0.39** (0.19)	0.019** (0.008)
Group D*Privatization	-5.67* (3.49)	-21.36** (9.14)		0.0004 (0.023)
REGULATION				
Group D	6.03 (4.97)	402.67 (380.55)	-1.60 (2.11)	-0.005 (0.03)
Regulation	3.06*** (1.12)	73.41 (120.71)	4.96*** (0.95)	-0.006 (0.007)
Group D*Regulation	-6.92*** (1.96)	-397.54** (185.61)	8.51*** (2.09)	-0.07*** (0.01)

7. *Evidence of Reform Outcomes from the Country Case Studies*

This section presents some snapshots of reform outcomes in four countries selected from Group A – namely Argentina, Jordan, South Africa and Indonesia - and four countries selected from Group D – namely Uganda, Kenya, Tanzania and Zambia.[2] The countries were selected to facilitate two comparisons of outcomes: one between Group A and Group D, and the other within each group between countries that have completed most of the reform stages and countries that have completed few reform stages.

The outcomes used for this comparison are the four indicators of power sector performance listed in Table 2 that are used to measure the determinants of power sector performance analysed in Section 4, namely residential access to electricity, energy sold per employee of electricity suppliers as an indicator of labour productivity, average electricity tariff level as an indicator of regulatory quality, and the index of carbon dioxide emissions as an indicator of environmental sustainability.

The milestones of power sector reform for these countries are shown in Figure 15 for the Group A countries and Figure 16 for the Group D countries. It is evident that all of these countries have tried to improve the performance of their power sectors. Argentina, Jordan and Uganda made the most progress in the reform process. South Africa, Indonesia, Tanzania and Zambia made the least progress in the reform process. According to the hypotheses tested in this paper among the Group A countries, Argentina and Jordan should have performed better in terms of the four indicators than South Africa and Indonesia. On the other hand according to these hypotheses, among the Group D countries the performance of Uganda and Kenya is not expected to be better than for Tanzania and Zambia. In short, unbundling and subsequently implemented reform stages are expected to be linked to an improvement in performance in Group A countries but not in Group D countries, after allowing for exogenous factors that affect performance.

The trends in these countries' performance indicators are shown in Figures 17 to 20. Access is shown in Figure 17. For Argentina and Jordan, the access rate increased from the mid-1990s to almost 100 percent by 2008, whilst in South Africa and Indonesia the access rate also increased steadily but up to 70 to 80 percent by 2008 from much lower levels in the mid-1990s. Given the difference in starting levels, all four Group A countries performed credibly on this indicator. For the Group D countries, all four countries had very low access rates and the comparison is inconclusive, because Kenya and Tanzania increased their access rates steadily, whereas Uganda and Zambia had setbacks in their access rates in the mid-2000s.

Labour productivity improved for all these countries in both groups when measured by an increase in the amount of energy sold per employee of electricity suppliers. This improvement was achieved by an increase in energy sales for all the countries and a reduction in the number of employees for some of the countries. Since employment level is one of the most contentious issues for power sector reform, it is worth noting that some countries that unbundled their power sectors reduced the number of employees - Argentina and Uganda, for example – while others that unbundled actually increased the number of employees - Jordan for example.

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[2] Zambia strictly falls just into Group C, but it is added in Group D in this case because it shares many common features to the three countries in Group D and its inclusion completes the desired sample for this Group.

Moreover, among the countries that did not unbundle their power sectors, some reduced the number of employees – South Africa, Indonesia, Tanzania and Zambia, for example, while none increased the number of employees. Hence no clear difference between extent of power sector reform and labour productivity emerges from this snapshot, as in the case of access.

Electricity tariffs and employment levels are generally contentious issues for power sector reform. In the four Group A countries, Argentina had very low tariffs, firstly on account of the success of the new wholesale electricity market, and then when capacity became short on account of political pressures to keep tariff levels down. South Africa and Indonesia also had very low tariffs under political pressure,[3] whilst Jordan's tariffs were sufficient to cover the cost of power supply but were not high by global standards. In the four Group D countries, Zambia had extremely low tariffs, and Uganda, Kenya and Tanzania kept tariffs at a moderate level. Hence no clear difference between extent of power sector reform and electricity tariff emerges from this snapshot.

Carbon dioxide emissions have not generally been one of the driving performance indicators for power sector reform in these countries. Any change to this indicator is therefore an incidental reform outcome in the sense that an increase in the index value does not necessarily indicate lack of success in achieving reform objectives, but instead shows where environmental and economic priorities can diverge. One example of this situation is where a country that has relied on hydropower increases its power generation from natural gas to reduce exposure to serious droughts and to provide a more economic portfolio of generation assets for meeting the demand for power. Argentina, Kenya, Uganda and Tanzania fall into this category, and hence their emissions index increased in the 2000s. Other countries – such as Jordan and Zambia – reduced their emissions index by switching from oil to natural gas in Jordans's case and from coal to hydropower in Zambia's case. No clear difference between extent of power sector reform and carbon dioxide emissions emerges from this snapshot.

[3] South Africa substantially increased its electricity tariffs in 2010.

Figure. 15
Milestones of Power Sector Reform in Four Group A Countries

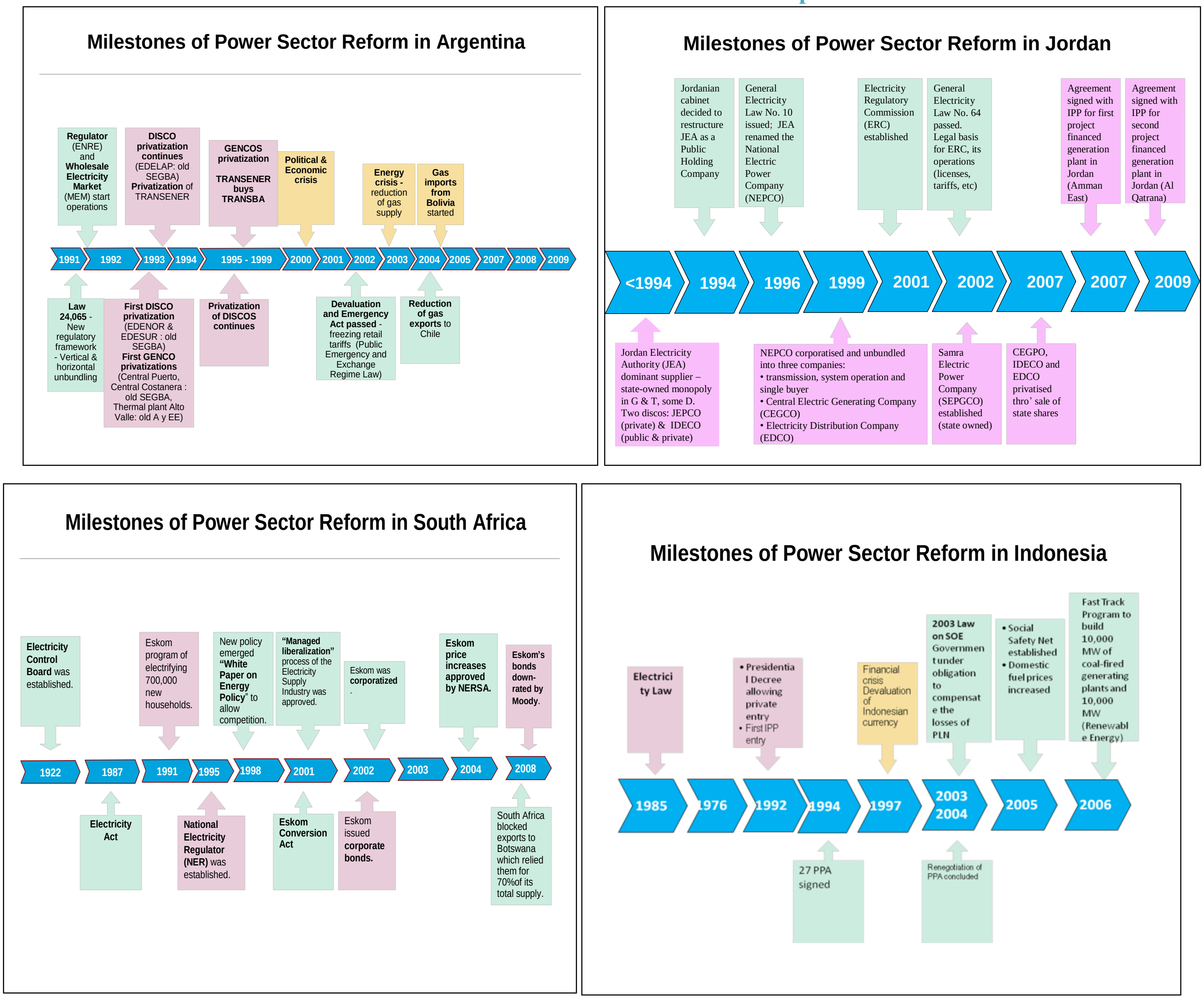


Figure. 16
Milestones of Power Sector Reform in Four Group D Countries

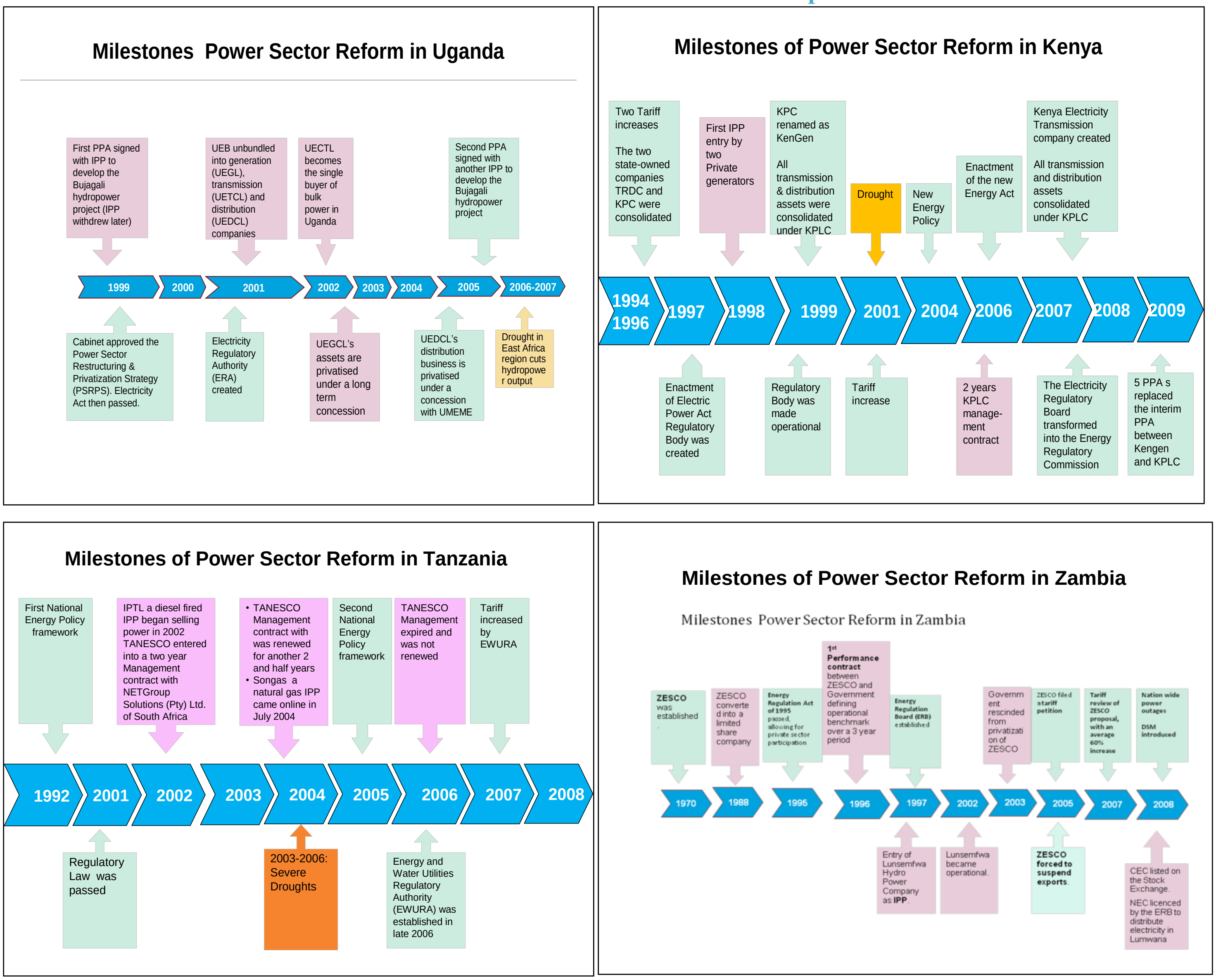
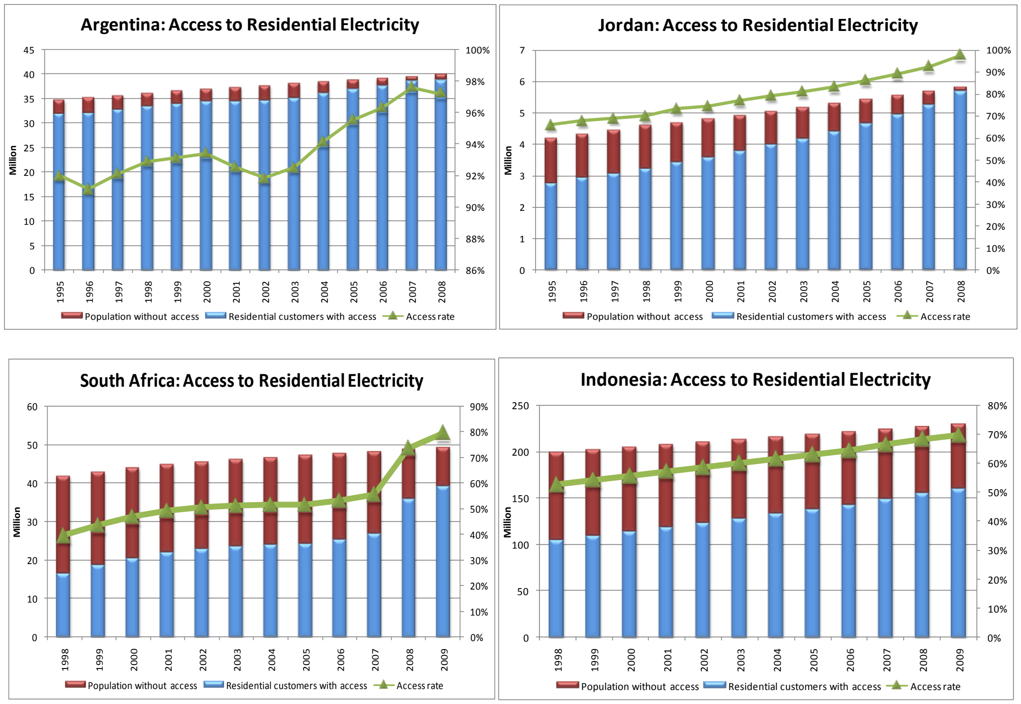


Figure. 17
Country Performance for Access to Electricity by Households in Groups A and D

Group A – Access



Group D – Access

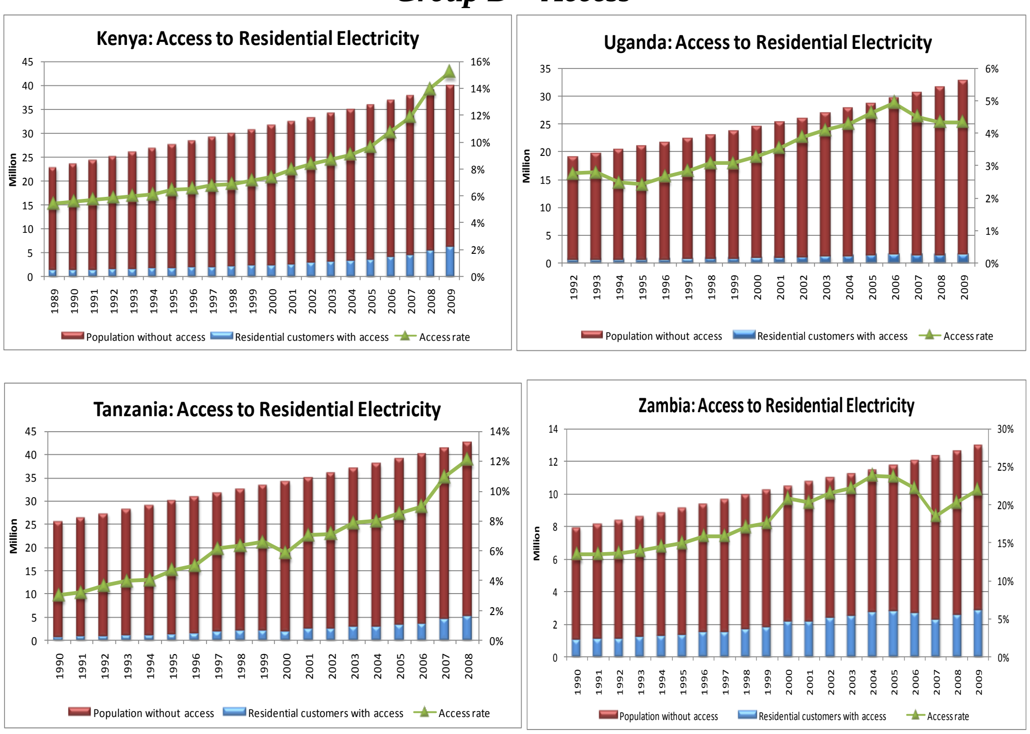
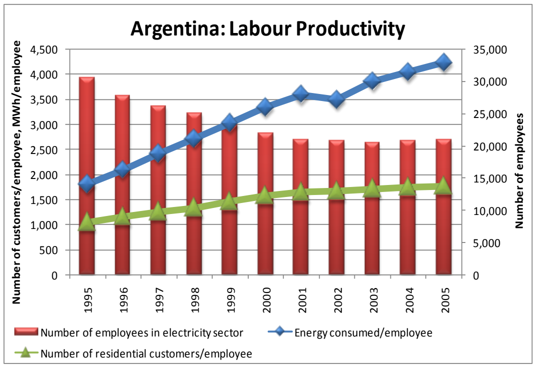
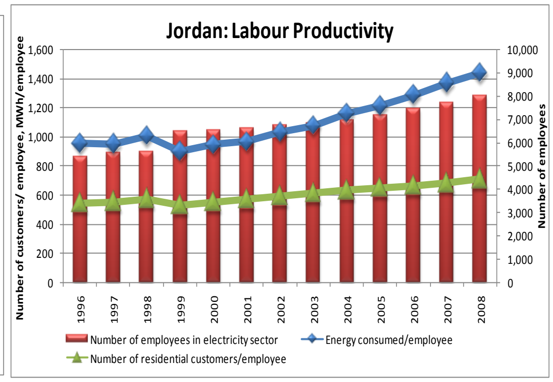
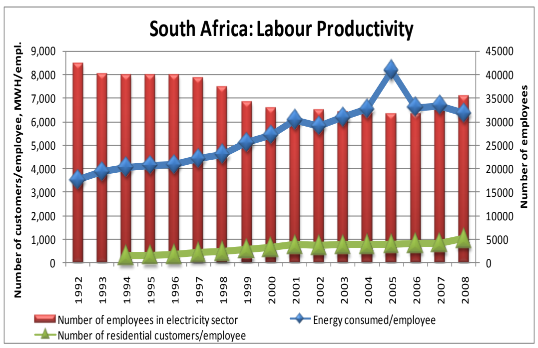


Figure. 18
Country Performance for Labour Productivity in Groups A and D

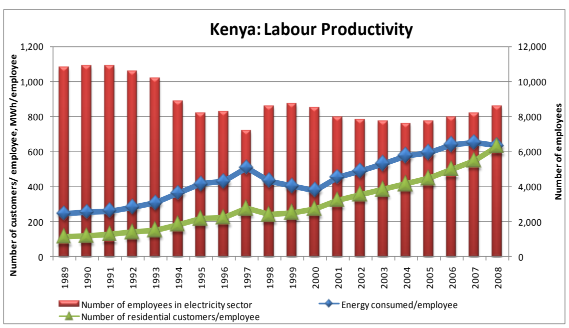
Group A – Labour Productivity

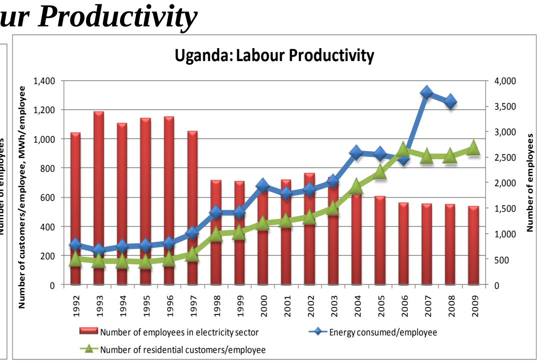


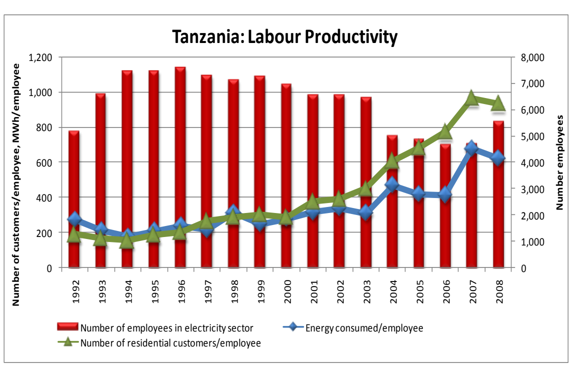




Group D – Labour Productivity







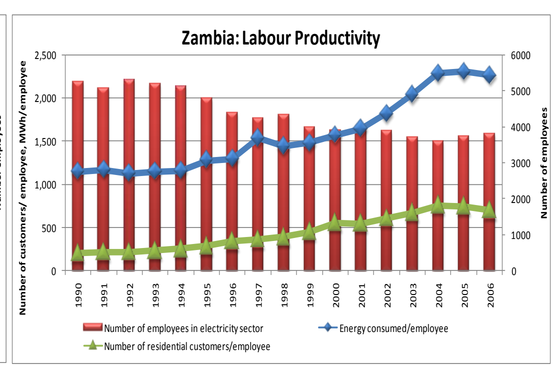
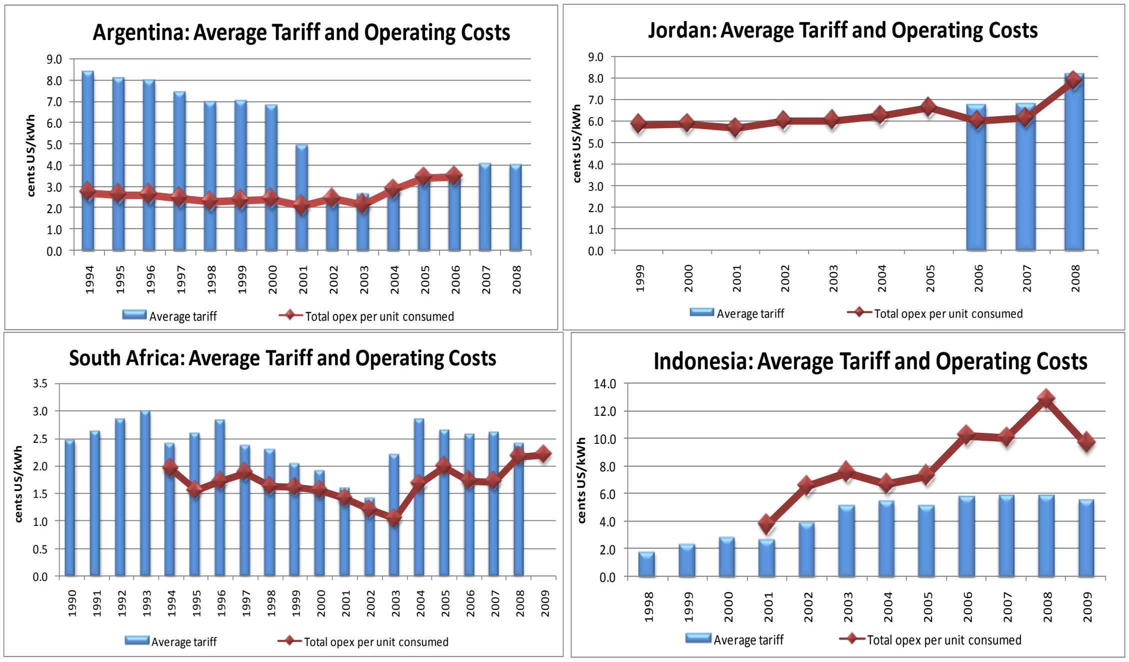


Figure 19
Country Performance for Tariffs in Groups A and D

Group A –Tariffs



Group D –Tariffs

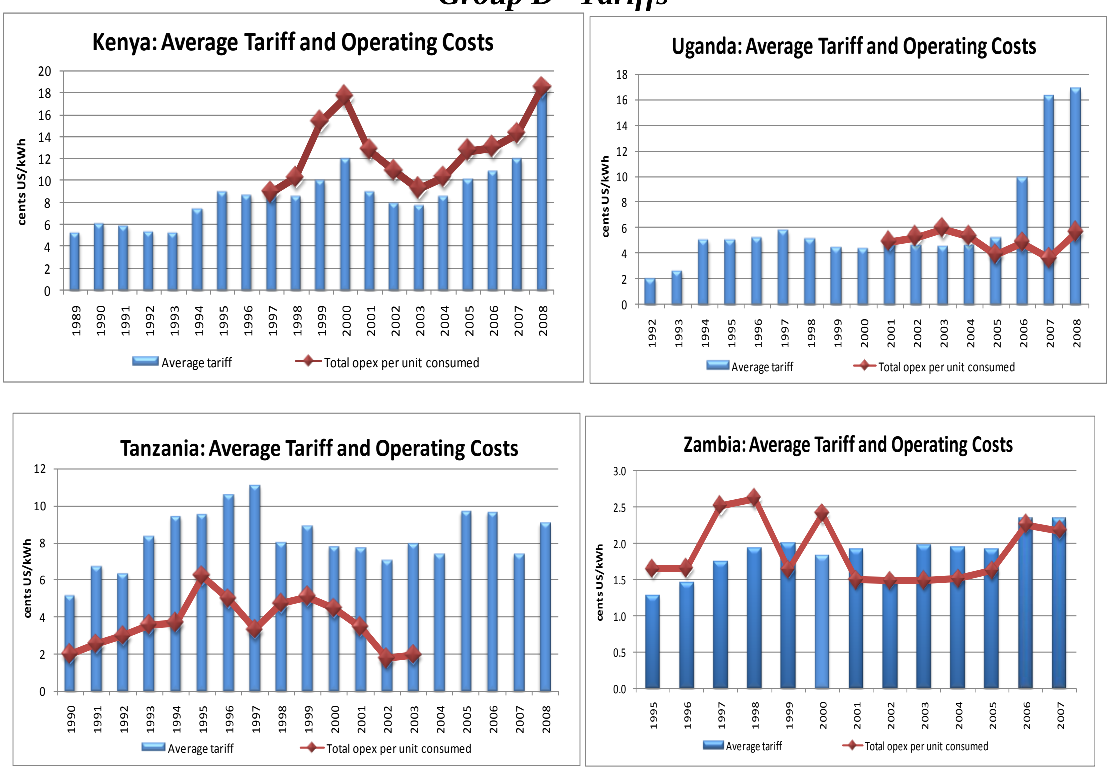
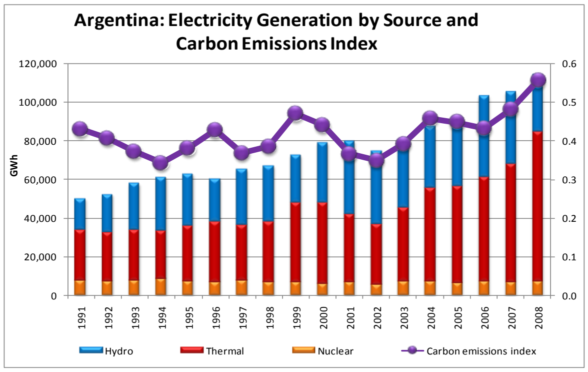
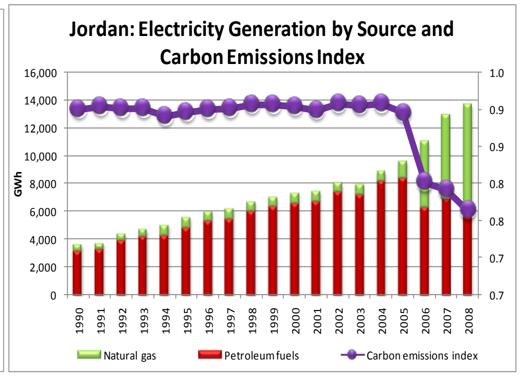
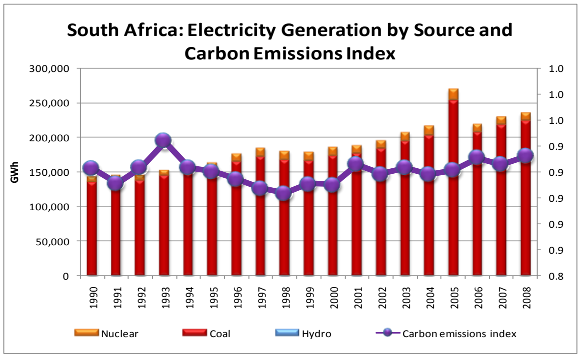


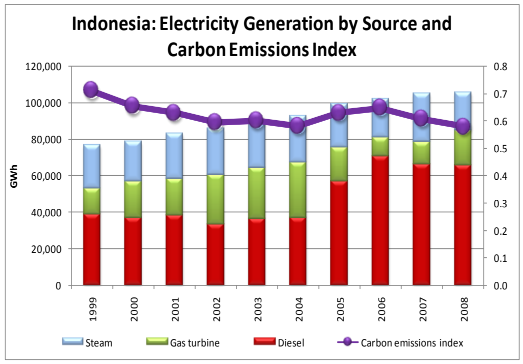
Figure 20
Country Performance for CO2 Emissions in Groups A and D

Group A –CO2 Emissions

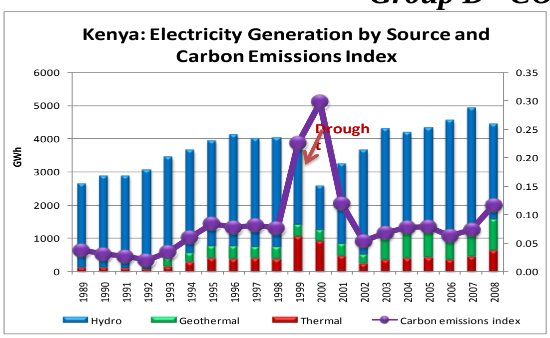


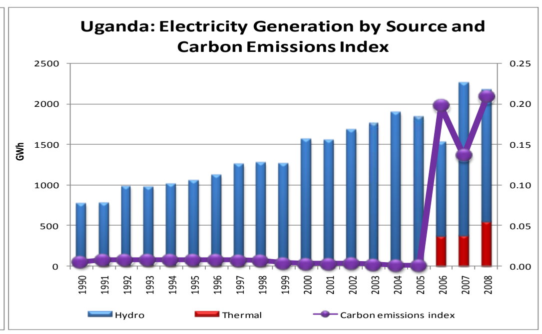


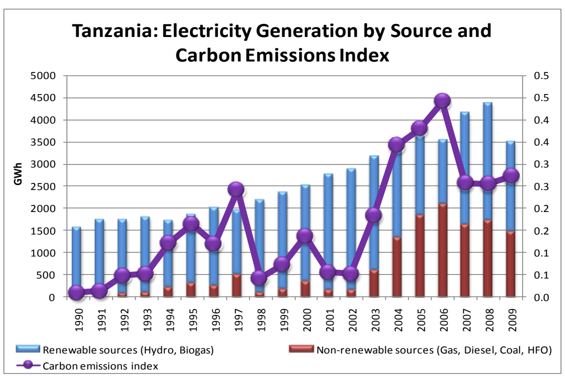


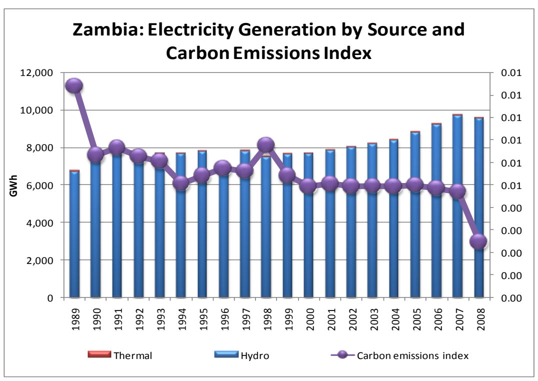


Group D –CO2 Emissions









8. Conclusions

Table 12 summarises the analytical evidence for these results. The results of the analysis carried out for this study confirm the following conclusions for policy guidance on power market restructuring for developing countries:

- ***Vertical unbundling deliver results in terms of*** several performance indicators when used as an entry point to implement broader reforms, particularly introducing a sound regulatory framework, reducing the degree of concentration of the generation and distribution segments of the market by attracting additional number of both public and private players and attract private sector participation.
- ***There seems to be credible empirical basis for selecting a threshold power system size and per capita income level*** below which unbundling of the power supply chain is not expected to be worthwhile.
- ***Partial forms of unbundling do not appear to drive improvements***, probably because the owner was able to continue exercising control over the affairs of the sector and hinder the development of competitive pressure within the power market.

The analysis with the regression model used for the study produces the following main findings for each of the reform indicators.

A. Vertical unbundling:

- ❖ The level of access is positively linked to full vertical unbundling, even if not significantly so. Partial unbundling is negatively and significantly associated with lower levels of access.
- ❖ The level of labor productivity (expressed in terms of energy sold per employee) is significantly reduced by both partial and full vertical unbundling.
- ❖ Full unbundling significantly enhanced the level of tariffs, whereas partial unbundling has no significant impact on tariffs.
- ❖ Partial and vertical unbundling is associated with higher carbon emissions, but only partial unbundling significantly so.

Differential impact of vertical unbundling in Groups A and D

- ❖ Vertical unbundling (in both specifications, namely either partial or full or full only) when interacted with Group A is significantly associated with enhanced access and more sustainable levels of CO2 emission generated by fossil fuels, reflecting both economic and environmental benefits to power users, due to increased efficiency of use of fossil fuels. The opposite result holds for Group D.
- ❖ There is no significant link between vertical unbundling and enhanced operational or financial efficiency for Group A, whereas there is a positive and significant link for Group D. This implies that for Group A the high prevailing level of labour productivity offers decreasing returns to scale, or there is an increasing use of outsourcing. For group

D the benefits of unbundling may be reflected mainly through restructuring and laying off of redundant employees.

B. Degree of disaggregation:

- The level of access is positively and significantly linked to the increase of disaggregation in generation. This result can be interpreted noting that developing countries have been able to scale up access after attracting more players and investment in generation.
- Labour productivity is enhanced by the increase of disaggregation in distribution. More players in distribution are expected to drive efficiency gains through means such as benchmark competition.
- More disaggregation in distribution drives electricity tariffs down, most likely as a result of benchmark competition and less collusion between players in the market.
- Higher competition in generation is significantly associated with higher sustainable environmental outcomes, reducing the carbon emissions from fossil fuels.

Differential impact of disaggregation in Groups A and D

- Higher disaggregation of the generation segment of the market when interacted with group A is significantly associated with enhanced access and more sustainable levels of CO2 emission generated by fossil fuels, reflecting the benefits to the users as well as to environment, due to increase efficiency of use of fossil fuels when more players are introduced. For Group D a trade off emerges between reduced access, but a more sustainable level of CO2 emission generated by fossil fuels.
- Reduction in the concentration of the distribution segment of the market for the countries belonging to Group A is positively and significant linked with enhanced operational efficiency, but there are no links with enhanced financial efficiency. This implies that for group of countries the already achieved in the level of tariff is already so high that there are decreasing returns to scale. Reduction in the concentration of the distribution segment of the market for the countries belonging to Group D is negatively linked with operational and financial efficiency, but not significantly so.

C. Regulation:

- ❖ The introduction of an autonomous regulator is significantly positively associated with higher access, confirming that regulators can also play an important role in ensuring that contracts were effectively designed.
- ❖ The presence of autonomous regulator has also significantly contributed to higher labor productivity, most likely by creating a more even playing field to attract private participation in distribution.
- ❖ The presence of an autonomous regulator is also significantly and positively associated with higher tariffs, reflecting the need to insulate crucial decisions related to pricing from political interferences.
- ❖ The presence of an autonomous regulator is also significantly associated with higher carbon emissions, proving that environmental considerations have a relatively lower priority compared to the traditional functions of energy policy and regulation, such as to protect consumers from high prices and ensure that power firms will be able to recoup their investment. These goals can be sometimes conflicting with each others.

Differential impact of regulation in Groups A and D

- ❖ The introduction of an autonomous regulator when interacted with Group A is significantly associated with enhanced access, higher operational efficiency, lower tariffs and more sustainable level of CO_2 emission generated by fossil fuels, reflecting the benefits to the users, producers as well as to environment, due to increase efficiency of use of fossil fuels. In contrast, the introduction of an autonomous regulator when interacted with Group D is significantly associated with reduced access, lower operational efficiency, higher tariffs, reflecting a lack of benefits to users and producers. It is however associated with more sustainable level of CO_2 emission generated from fossil fuels, as well as to environment. This result underscores the challenges in implementing regulatory reforms in this group of countries.

D. Private Sector Participation:

- ❖ The introduction of private sector participation in generation also is significantly linked to access expansions, proving that IPPs and divestiture of formerly state-owned generators can deliver positive results. The introduction of private sector participation also helped to significantly enhance operational efficiency and labor productivity in distribution.
- ❖ A higher share of private sector participation significantly raises the level of tariffs, most likely reflecting the need to raise tariffs to attract private participation in distribution.
- ❖ Private ownership in generation is also significantly and positively associated with less environmental sustainable outcomes, raising the carbon emissions from burning fossil fuels.

Differential impact of private sector participation in Groups A and D

- ❖ The introduction of private sector participation in the generation segment of the market when interacted with Group A is not significantly associated with access or carbon emissions generated from fossil fuels. This implies that for countries belonging to Group A, the achieved level of access is already so high that privatization of generation is not sought to enhance connectivity. There is also no significant evidence of environmental unsustainability results brought by the private sector in generation. The introduction of private sector participation in the generation segment of the market when interacted with Group D is significantly associated with reduced level of access but is not significantly linked to the carbon emission generated by fossil fuels.

- The introduction of private sector participation in the distribution segment of the market for the countries belonging to Group A is positively and significant linked with enhanced operational efficiency, but there are no links with enhanced financial efficiency. In the case of financial efficiency, instead, the overall link between private sector participation in distribution and tariff was positive and significant, reflecting the fact that in order to attract the private sector more cost reflective tariffs were needed. This seems to imply that for Group A of countries the already achieved level of tariff is already found enough to attract private sector participation in distribution. The introduction of private sector participation in the distribution segment of the market for the countries belonging to Group D is negatively and significantly linked with operational efficiency, but there are no links with enhanced financial efficiency.

E. Control variables:

- As expected, countries characterized either by higher income countries or larger system size are characterized by significantly higher levels of access, labour productivity and tariffs. The links with environmentally sustainable outcomes are instead different. Ceteris paribus, as one would expect, higher income countries are positively associated to higher carbon emissions, whereas countries characterized by larger system size are negatively and significantly associated to lower carbon emissions. The latter result is most likely due to the presence of economies of scale and the fact that smaller and isolated systems are in many cases mostly dependent on oil imports and find it more difficult to diversify sources of energy.

- The interacted term between GDP per capita and power system size is negative, revealing decreasing returns to scale by the highest income countries - such as OECD countries - which have already achieved close to universal access and face an exponentially increasing cost in connecting each new consumer as they approach full coverage. The explanatory power of these variables is very high, reaching 90% in the preferred specification of random effects.

Table 12
Summary of Analytical Evidence

	Access		Labor Productivity		Tariff		Emissions Index	
Group	A	D	A	D	A	D	A	D
VERTICAL UNBUNDLING (EITHER PARTIAL OR FULL)								
Unbundling	-		-		$+^{**}$		$+^{*}$	
Unbundling* Group	$+^{***}$	$-^{***}$	-	$+^{*}$	-	+	$-^{**}$	$+^{**}$
FULL VERTICAL UNBUNDLING								
Full Unbundling	+		$-^{*}$		$+^{***}$		+	
Full Unbundling* Group	$+^{***}$	$-^{***}$	-	$+^{*}$	$-^{***}$	$+^{***}$	$-^{***}$	$+^{***}$
DEGREE OF DISAGGREGATION								
Disaggregation	$+^{***}$		+		$-^{***}$		$-^{***}$	
Disaggregation* Group	$+^{***}$	$-^{***}$	$+^{**}$	-	+	-	$-^{***}$	$-^{***}$
REGULATION								
Regulation	$+^{***}$		$+^{***}$		+***		-***	
Regulation* Group	$+^{***}$	$-^{***}$	$+^{***}$	$-^{**}$	$-^{***}$	$+^{***}$	$+^{***}$	$-^{***}$
PRIVATIZATION								
Privatization	$+^{***}$		$+^{***}$		$+^{**}$		$+^{***}$	
Privatization* Group	+	$-^{*}$	$+^{**}$	$-^{**}$	+	-	-	+
CONTROL VARIABLES								
GDP per capita	$+^{***}$		$+^{***}$		$+^{***}$		+	
Installed capacity	$+^{***}$		$+^{***}$		$+^{***}$		$-^{***}$	
GDP per capita*Capacity	$-^{***}$		$-^{***}$		$-^{***}$		$+^{***}$	
EXPLANATORY POWER								
Within R^2 (fixed effect)	64		90		54		22	
Between R^2 (random effect)	92		77		52		30	

8. Directions for New Research

- For the purposes of this research the countries in the sample were divided into different categories based on the specific threshold levels of system size and income. The selected thresholds are in line with the previous research (Besant-Jones, 2006). The alternative way of categorizing countries would be to apply a cluster analysis. This technique allows assigning a set of observations into subsets, such that observations in the same subset are similar in some parameters (for example, GDP per capita and power system size), but that the subsets differ between each other. The application of the cluster analysis allows obtaining the optimal number of subsets as well as the threshold levels based on the underlying data.
- Different definitions of the aggregate index of reforms can be used to examine the robustness of the results to the different specifications. More sophisticated dynamic error correction models and the instrumental variable approach to allow for potential possible endogeneity biases can be used in future research.
- Finally, additional performance indicators, including indicators of quality (such as SAIDI and SAIFI), operational efficiency (including capacity utilization, load factor), financial efficiency (such as cost recovery index), and long run environmentally sustainability indicators (such as the share renewables) and energy endowment (such as reserve capacity, and self-sufficiency) can be studied in more detail with the help of the econometric models.

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Appendix 1
Fixed and Random Effects Specification

We run the specifications of the model using both Fixed Effects (FE) and Random Effects (RE) regressions as specified below:

(1) FE $\mathbf{Y}_{it}=\alpha_i+\boldsymbol{\beta}'\mathbf{X}_{it}+\varepsilon_{it}$ where $\varepsilon_{it} \sim$ IID $(0, \sigma_\varepsilon)$

(2) RE $\mathbf{Y}_{it}=\alpha+\boldsymbol{\beta}'\mathbf{X}_{it}+u_i + w_{it}$ where $\varepsilon_{it} = u_i + w_{it}$ and $u_i \sim$IID $(0, \sigma_u)$ and $\varepsilon_{it} \sim$ IID $(0, \sigma_\varepsilon)$

u_i are assumed independent of w_{it} and $\mathbf{X}_{it}$ which are also independent of each other for all i and t

i and *t* represent unit of observation (in our case countries) and time period, respectively

$\mathbf{Y}_{it}$ is dependent variable (that is, performance indicators, represented by access, operational and financial efficiency and environmental sustainability).

$\boldsymbol{\alpha}_i$ is the individual effect

$\boldsymbol{\beta}'$ is the inverted vectors of parameters to be estimated

$\mathbf{X}_{it}$ includes both reform variables and control variables (GDP per capita and installed system capacity).

ε_{it} is the vector of random disturbances

We then select the most appropriate specification using the Hausman and Breusch and Pagan test (described below).

In FE model, the country-specific effects (α_i) are assumed to be the fixed parameters to be estimated. In RE model, the country-specific effects (α) are treated as stochastic. The fixed effects model is a reasonable approach when we can be confident that the differences between units (in our case, countries) can be viewed as parametric shifts of the regression function. This model may be viewed as only applicable to the cross-sectional units in the study, not to additional ones outside the sample. In another setting, as it may be in our case, when for example the sampled cross-sectional units were drawn from a large population, it may be more appropriate to view individual specific constant terms as randomly distributed across cross-sectional units.

A FE model is estimated by ordinary least squares (OLS) which is a matrix weighted average of the within and between units estimators. A random effect model is estimated by generalized least squares (GLS) when the variance structure is known and feasible generalized least squares (FGLS) when the variance is unknown. The fixed effect model produces consistent estimates, whereas the estimates obtained from the random effect model is more efficient but the estimates may be inconsistent. The inefficiency of least squares follows from an inefficient weighting of the two (within and between) least squares estimators. In particular compared to the GLS, OLS places too much weight on the between unit variation. It includes all in the variation in X, rather than apportioning some of it to random variation across groups attributable to the variation in u across units. The inconsistency of the random effect model derives from the fact that there is no justification for treating the individual effects as uncorrelated with the other regressors so that it may suffer from the inconsistancy due to omitted variables.

The Hausman specification test compares the fixed versus random effects under the null hypothesis that the individual effects are uncorrelated with the other regressors in the model (Hausman 1978). If correlated (namely if the null hypothesis is rejected), a random effect model produces biased estimators, violating one of the Gauss-Markov assumptions; so a fixed effect model is preferred. Hausman's essential result is that the covariance of an efficient estimator with its difference from an inefficient estimator is zero (Greene 2003).

Breusch and Pagan (1980) developed the Lagrange multiplier (LM) test (Greene 2003; Judge et al. 1988) to identify the presence of random effects and in order to decide on using either pooled OLS or random effects in our analysis. The null hypothesis is that cross-sectional variance components are zero. The LM is distributed as chi-squared with one degree of freedom. If the null is rejected, the random effect model is more appropriate.

Appendix 2
List of performance indicators included in the database

Whereas the outcomes used for our econometric as well as our case study analysis are selected one, the database include indicators of access (namely residential access to electricity), quality (such as SAIDI and SAIFI), operational efficiency (such as energy sold per employee of electricity supplied , capacity utilization, load factor), financial efficiency (such as the average level of tariff and the cost recovery index), and environmentally sustainability indicators (such as the index of carbon dioxide emissions and the share of renewable energy in generation) and energy endowment (such as reserve capacity, and self-sufficiency), as reported in the Table below.

Variables		Definition
ACCESS		
Residential Access (% population)	=	number of residential connections divided by the total population
QUALITY		
SAIDI (hours per customer)	=	System Average Interruption Duration Index. Average duration of interruptions to power supply experienced by a consumer.
SAIFI (number per customer)	=	System Average Interruption Frequency Index. Average number of interruptions to power supply experienced by a consumer.
OPERATIONAL EFFICIENCY		
Energy sold per employee (MWh per employee)	=	amount of the energy consumed from the interconnected system divided by the number of employees of the power supply entities for the whole power market
Capacity Utilization (%)	=	amount of energy generated divided by the total nominal generating capacity on the interconnected system
Load Factor (%)	=	output of a power plant divided by the maximum output it can produce
FINANCIAL EFFICIENCY		
Tariff Level (US$c per KWh)	=	average tariff
Cost Recovery Index (%)	=	ratio of average revenue yield divided by average supply cost for all distributors as a group
Debt Ratio (%)	=	utilities' equity divided by liability
ENVIRONMENTAL SUSTAINABILITY		
Carbon Emission Index (CO_2 ton/Kwh)	=	energy generated from each fuel weighted with the following coefficients of CO_2 emission intensity by weight per unit of electricity generated divided by total amount of energy generated (coal = 1.00; petroleum fuels = 0.94; natural gas = 0.63; renewable energy, and nuclear power = zero)
Share Renewable (%)	=	amount of energy generated from renewable sources to the total amount of energy generated
ENERGY ENDOWMENT		
Reserve Capacity (%)	=	(available capacity during peak demand (MW)/peak demand (MW)) - 1
Self Sufficiency (%)	=	proportion of total bulk energy supply derived from domestic energy resources

Appendix 3
Testing Hypotheses for the set of indicators

To get an initial indication from the data of whether the hypotheses we moved forward are confirmed, we can calculate the two means between different groups (e.g. the proportion of investment for the observations where vertical unbundling has been introduced) and compare them to see if one is greater than the other, and by how much. The significance of differences between two sample means can be assessed using the t-statistic calculated as part of the t-test. The t-statistic may be thought of as a scaled difference between the two means, where the absolute difference between means is rescaled using an estimate of the variability of the means. The results of the t-tests reveal the following trends.

The percent of population with access to electric service is significantly higher in the systems characterized by the presence of an autonomous regulator, vertical unbundling, higher levels of disaggregation both in generation and in distribution sectors, and higher share of private ownership. All results of the t-tests on access are statistically significant at one percent level.

Regarding quality, the graphs indicate that levels of SAIDI (duration of outages) and SAIFI (frequency of outages) tend to be lower in more liberalized systems. Statistical significance of the results of t-tests on quality varies across market structure variables.

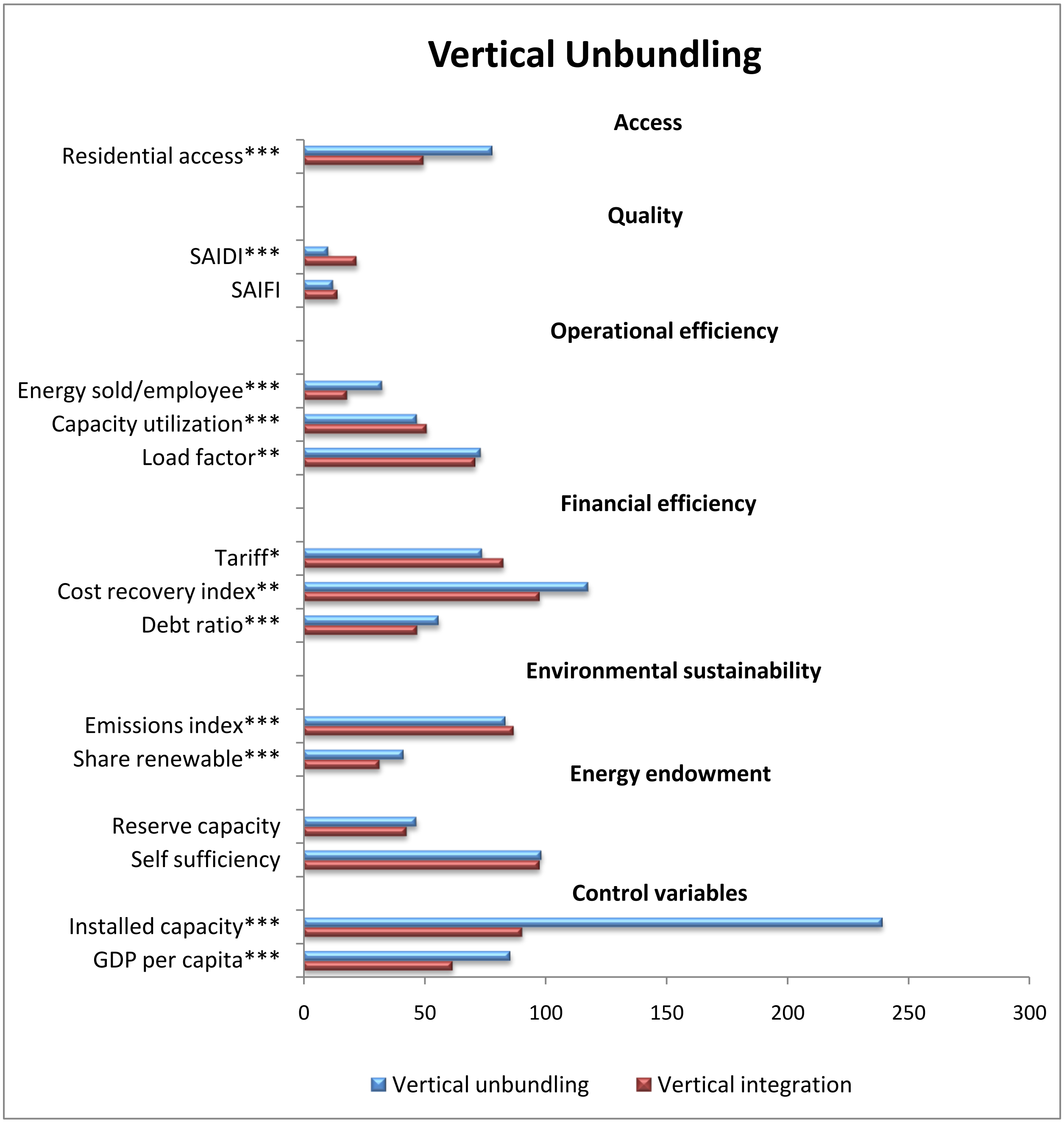
With respect to the relation between market structure and operational efficiency, the results of t-tests provide mixed evidence. While capacity utilization tends to be lower in more liberalized systems, load factor in such systems is generally higher. The results of t-tests on labor productivity that are statistically significant vary: energy sold per employee is higher when the generation sector is less concentrated, when the system is vertically unbundled, and when an independent regulator is present, and it is lower when the share of private ownership is higher.

T-tests were also applied to three indicators of financial efficiency. The tariff level is lower when the system is vertically unbundled and when there is more competition in the distribution sector, but it is higher in the presence of an autonomous regulator and a higher share of private ownership. Cost recovery index is higher in all cases. Debt ratio appears to be affected by the market structure variables in different ways.

According to t-tests, more liberalized market conditions are beneficial to the environment. All the graphs indicate lower emissions levels and higher reliance on renewable sources (except in the case of higher private ownership, though the result is not statistically significant).

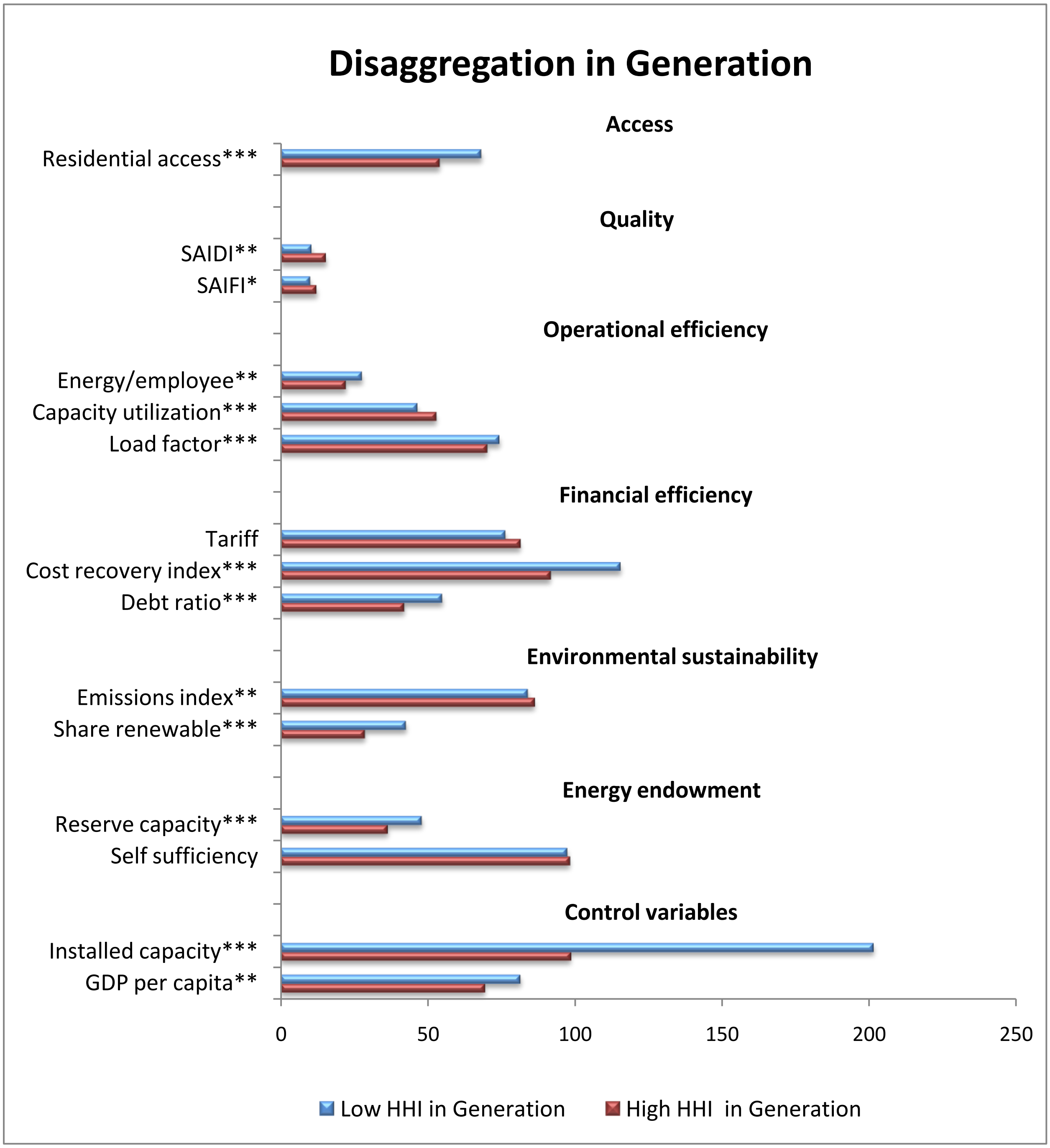
Energy security seems also to be positively affected by higher market disaggregation, presence of an autonomous regulator, and a higher degree of private ownership. Graphs depict higher levels of reserve capacity and self-sufficiency, except in the case of higher disaggregation in generation (not a statistically significant result).

The last two graphs illustrate relations of two key control variables (GDP per capita and installed capacity) and performance parameters. Not surprisingly, population of the countries with higher income and large system sizes tend to enjoy better access to electric service and higher quality of this service. Larger system size is associated with higher labor productivity, lower capacity utilization, higher load factor, lower tariffs, lower emissions index, lower share of renewable, and higher degree of self-sufficiency. Higher income is associated with higher labor productivity, lower load factor, higher cost recovery index, lower debt ratio, higher emissions index, lower share of renewable, higher reserve capacity, and lower self-sufficiency.



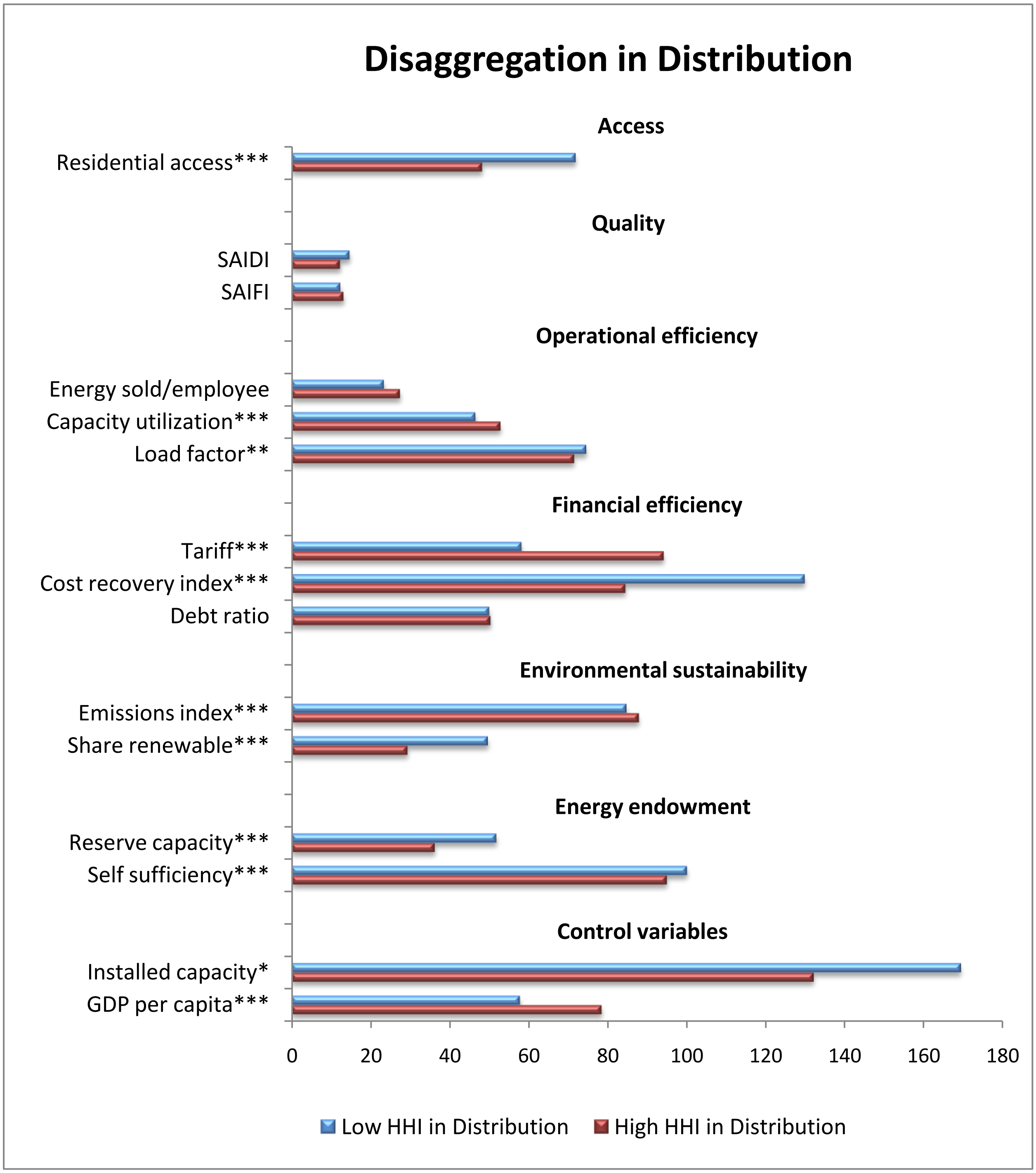
Note: The following adjustments were made to make the indicators fit in the same figure. Tariff ($US cent per MWh) instead. Emissions index (that is measured as a number from 0 to 1) was multiplied by 100. Energy sold per employee (measured in MWh per employee), Installed capacity (measured in MW), and GDP per capita (measured in $US) were divided by 100.

	Vertical unbundling	Vertical integration	t
Residential access * (% population)**	78.4 (28.1)	49.3 (34.3)	-8.7
SAIDI***	10.4 (10.9)	22.6 (22.8)	4.0
SAIFI	12.8 (12.2)	14.3 (8.3)	.8
Energy sold per employee***	33.6 (28.18)	18.7 (17.17)	-4.9
Capacity utilization***	46.6 (15.9)	51.0 (11.7)	2.8
Load factor**	73.5 (8.3)	71.0 (9.3)	-1.7
Tariff*	75.4 (3.2)	82.6 (5.3)	1.5
Cost recovery index**	110.9 (64.3)	97.5 (45.9)	-2.1
Debt ratio***	57.3 (23.8)	47.1 (24.5)	-2.2
Emissions index***	83.7 (6.4)	86.8 (9.3)	3.5
Share renewable***	41.9 (28.5)	32.1 (33.8)	-3.1
Reserve capacity	46.9 (35.0)	42.7 (19.1)	-1.2
Self sufficiency	98.5 (6.6)	97.5 (17.3)	-.7
Installed capacity***	244.7 (257.4)	90.4 (120.5)	-7.9
GDP per capita***	85.7 (60.4)	61.7 (63.3)	-3.9



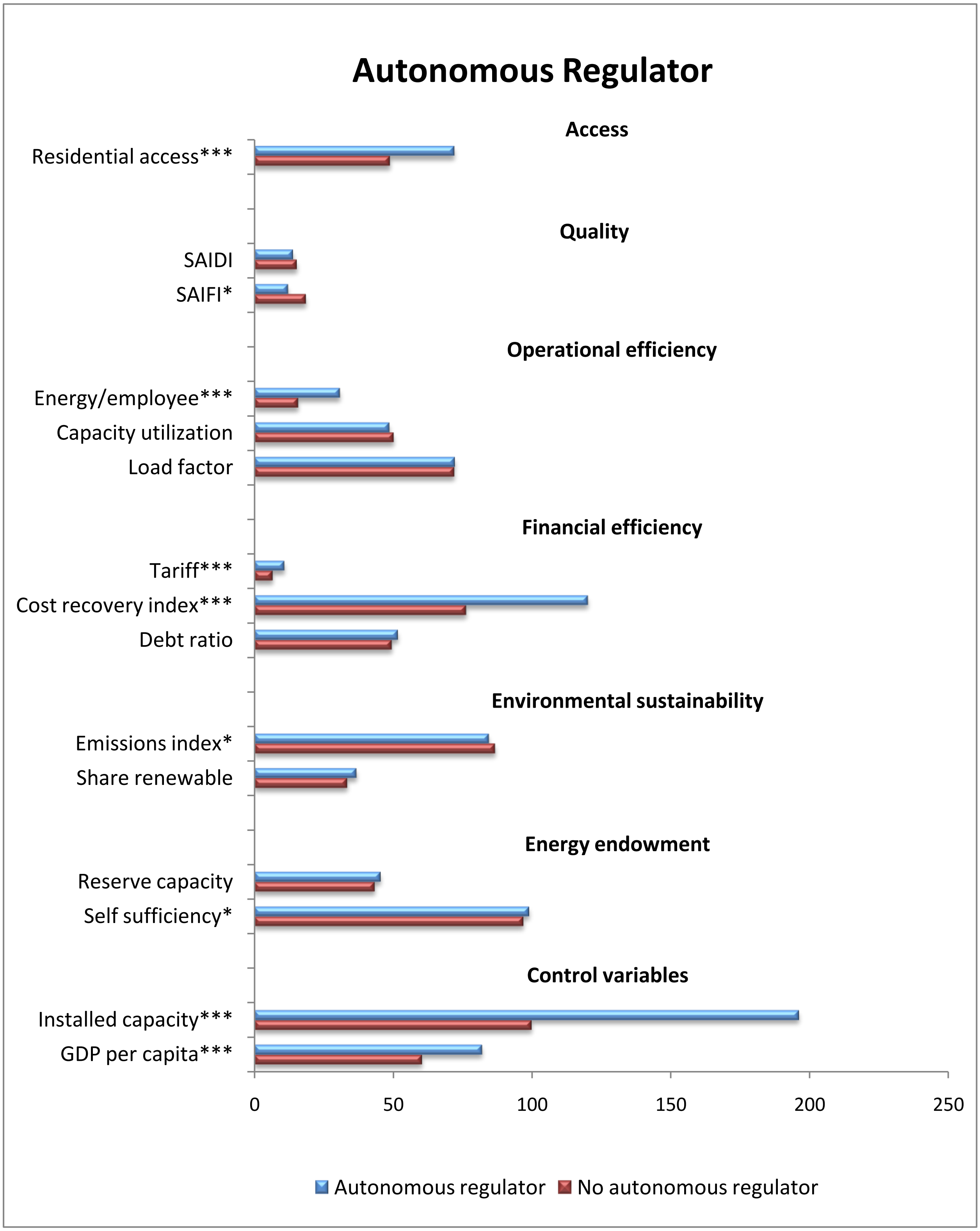
Note: The following adjustments were made to make the indicators fit in the same figure. Tariff ($US cent per MWh) instead. Emissions index (that is measured as a number from 0 to 1) was multiplied by 100. Energy sold per employee (measured in MWh per employee), Installed capacity (measured in MW), and GDP per capita (measured in $US) were divided by 100.

	Low HHI in Generation	High HHI in Generation	t
Residential access * (% population)**	68.3 (36.1)	53.9 (32.5)	3.6
SAIDI**	10.5 (11.7)	15.5 (20.2)	-1.6
SAIFI*	10.4 (6.6)	12.3 (8.5)	-1.3
Energy sold per employee**	29.0 (27.5)	22.2 (19.8)	1.7
Capacity utilization***	46.1 (14.8)	52.8 (10.9)	-4.4
Load factor**	74.4 (9.0)	70.1 (8.5)	2.9
Tariff	77.6 (27.7)	81.4 (60.7)	-.8
Cost recovery index***	108.6 (57.4)	91.6 (46.9)	2.4
Debt ratio***	55.8 (22.4)	42.1 (23.1)	3.1
Emissions index**	84.1 (5.9)	86.2 (10.1)	-2.1
Share renewable***	43.9 (23.3)	28.6 (36.9)	3.9
Reserve capacity***	48.0 (29.6)	36.4 (19.2)	3.6
Self sufficiency	97.5 (12.6)	98.2 (16.2)	.4
Installed capacity***	206.4 (250.5)	98.5 (135.2)	4.9
GDP per capita**	81.6 (64.8)	69.4 (64.6)	1.7



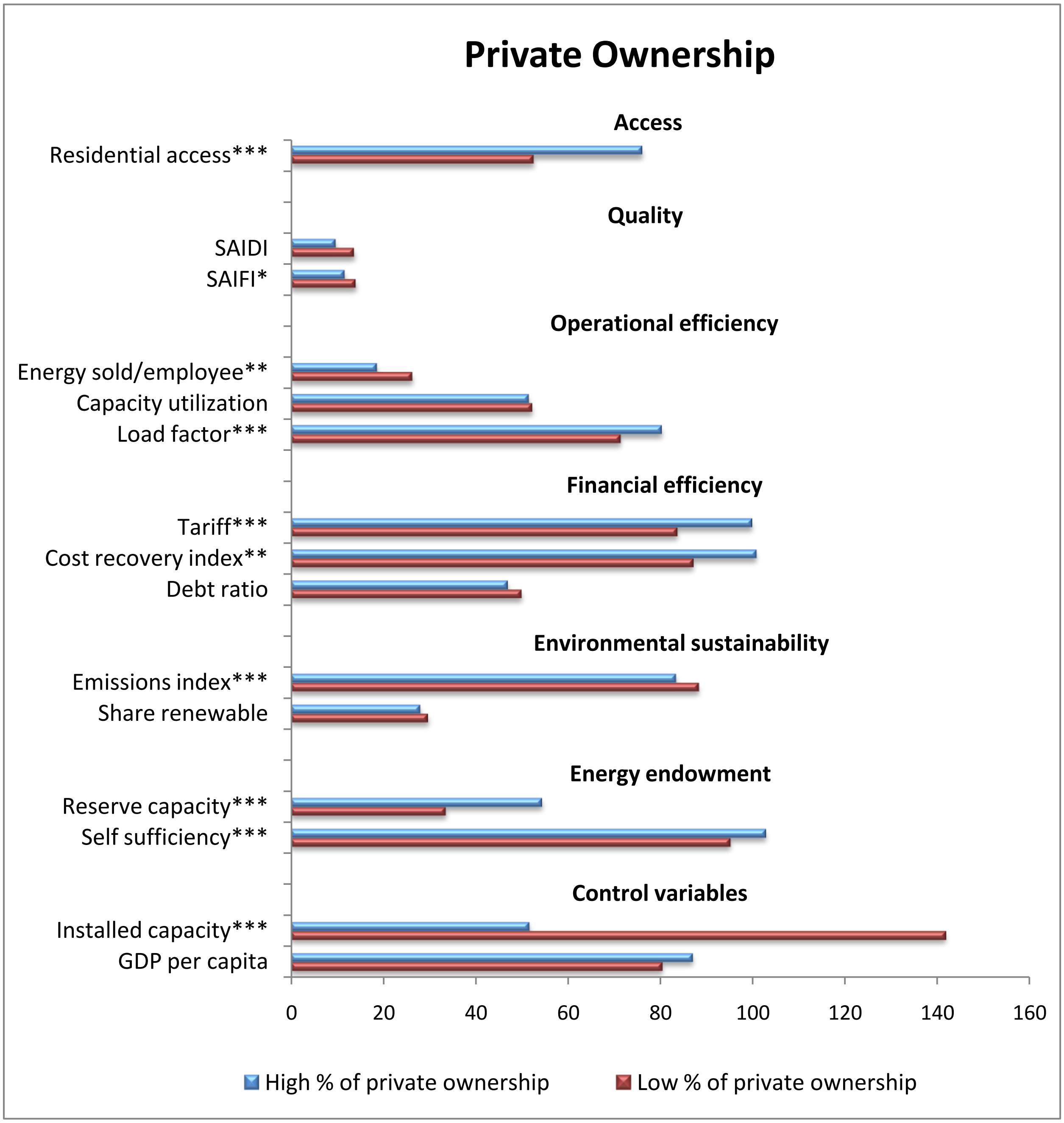
Note: The following adjustments were made to make the indicators fit in the same figure. Tariff ($US cent per MWh) instead. Emissions index (that is measured as a number from 0 to 1) was multiplied by 100. Energy sold per employee (measured in MWh per employee), Installed capacity (measured in MW), and GDP per capita (measured in $US) were divided by 100.

	Low HHI in Distribution	High HHI in Distribution	t
Residential access * (% population)**	71.9 (28.5)	48.3 (36.3)	5.6
SAIDI	14.7 (9.8)	12.3 (19.7)	.8
SAIFI	12.4 (7.2)	13.2 (6.9)	-.5
Energy sold per employee	23.4 (13.5)	27.5 (28.5)	-1.2
Capacity utilization	46.6 (15.8)	52.9 (11.0)	-4.0
Load factor	74.6 (10.8)	71.5 (8.3)	1.8
Tariff* **	58.2 (29.3)	94.2 (49.1)	-5.8
Cost recovery index* **	129.9 (51.7)	84.5 (38.2)	5.9
Debt ratio	50.1 (24.7)	50.4 (23.9)	-.1
Emissions index* **	84.8 (3.9)	87.9 (8.2)	-3.6
Share renewable* **	49.7 (33.8)	29.4 (32.9)	5.2
Reserve capacity* **	51.9 (28.6)	36.3 (21.6)	4.5
Self sufficiency* **	100.1 (9.0)	95.0 (17.5)	2.7
**Installed capacity* **	169.4 (261.2)	132.2 (179.9)	1.5
GDP per capita* **	57.8 (37.6)	78.5 (72.2)	-2.8



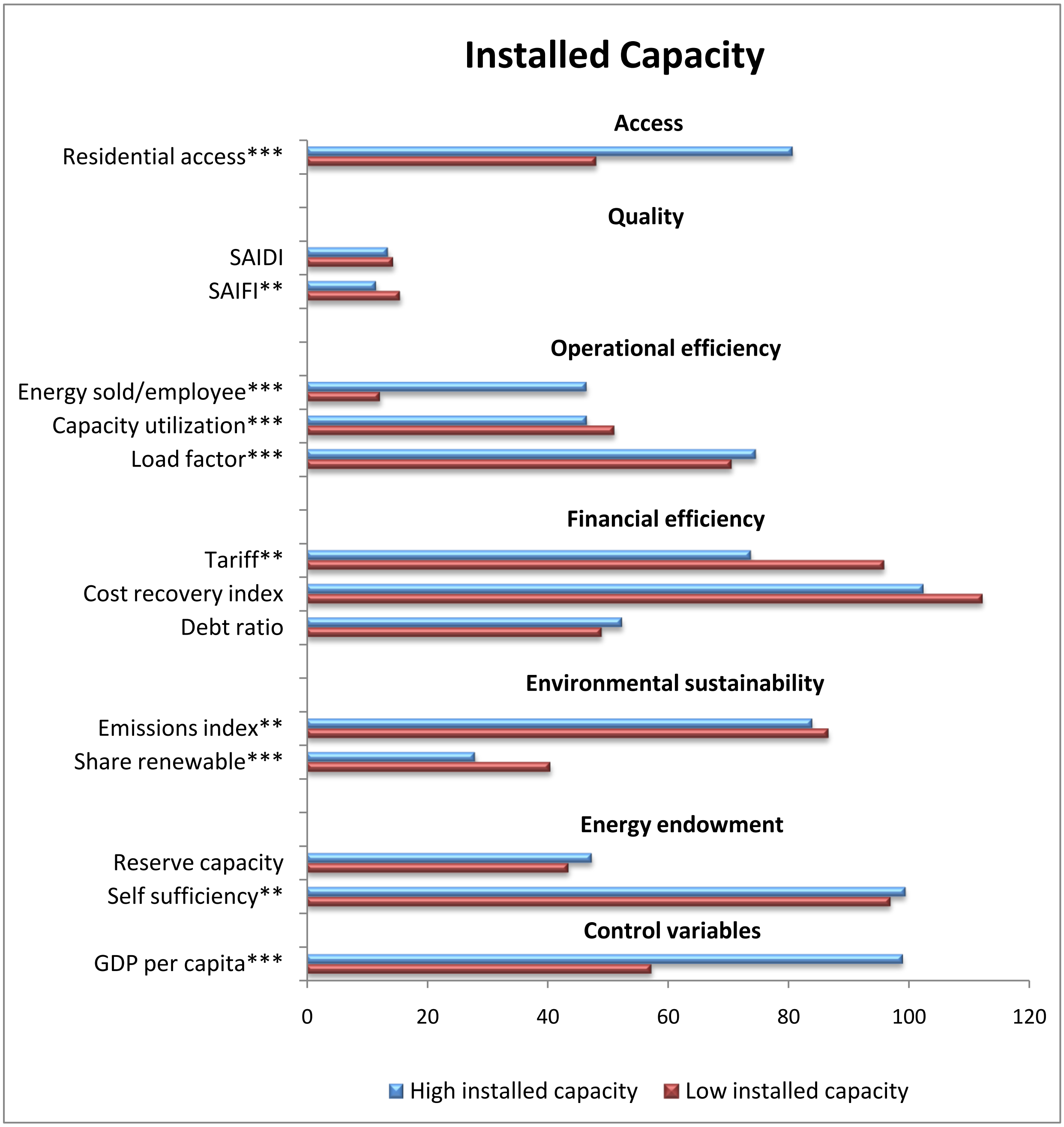
Note: The following adjustments were made to make the indicators fit in the same figure. Tariff ($US cent per MWh) instead. Emissions index (that is measured as a number from 0 to 1) was multiplied by 100. Energy sold per employee (measured in MWh per employee), Installed capacity (measured in MW), and GDP per capita (measured in $US) were divided by 100.

	Autonomous Regulator	No autonomous Regulator	t
Residential access * (% population)**	72.1 (31.3)	48.9 (34.8)	-6.7
SAIDI	13.9 (16.0)	15.4 (19.2)	.4
SAIFI*	12.4 (9.7)	18.6 (15.3)	2.2
Energy sold per employee***	32.1 (25.3)	15.8 (17.8)	-5.1
Capacity utilization	48.3 (15.5)	50.2 (11.8)	1.0
Load factor	72.3 (8.5)	71.9 (9.5)	-.2
Tariff***	86.1 (5.1)	66.9 (2.7)	-3.5
Cost recovery index***	115.6 (58.7)	76.3 (34.6)	-4.4
Debt ratio	52.3 (24.3)	49.5 (25.8)	-.5
Emissions index*	84.5 (8.4)	86.7 (8.4)	2.5
Share renewable	37.5 (31.7)	33.9 (32.8)	-1.1
Reserve capacity	45.5 (27.9)	43.4 (27.7)	-.6
Self sufficiency*	99.0 (10.9)	96.8 (16.5)	-1.5
Installed capacity***	200.3 (237.2)	99.8 (137.7)	-5.1
GDP per capita***	82.1 (65.9)	60.3 (59.3)	-3.6



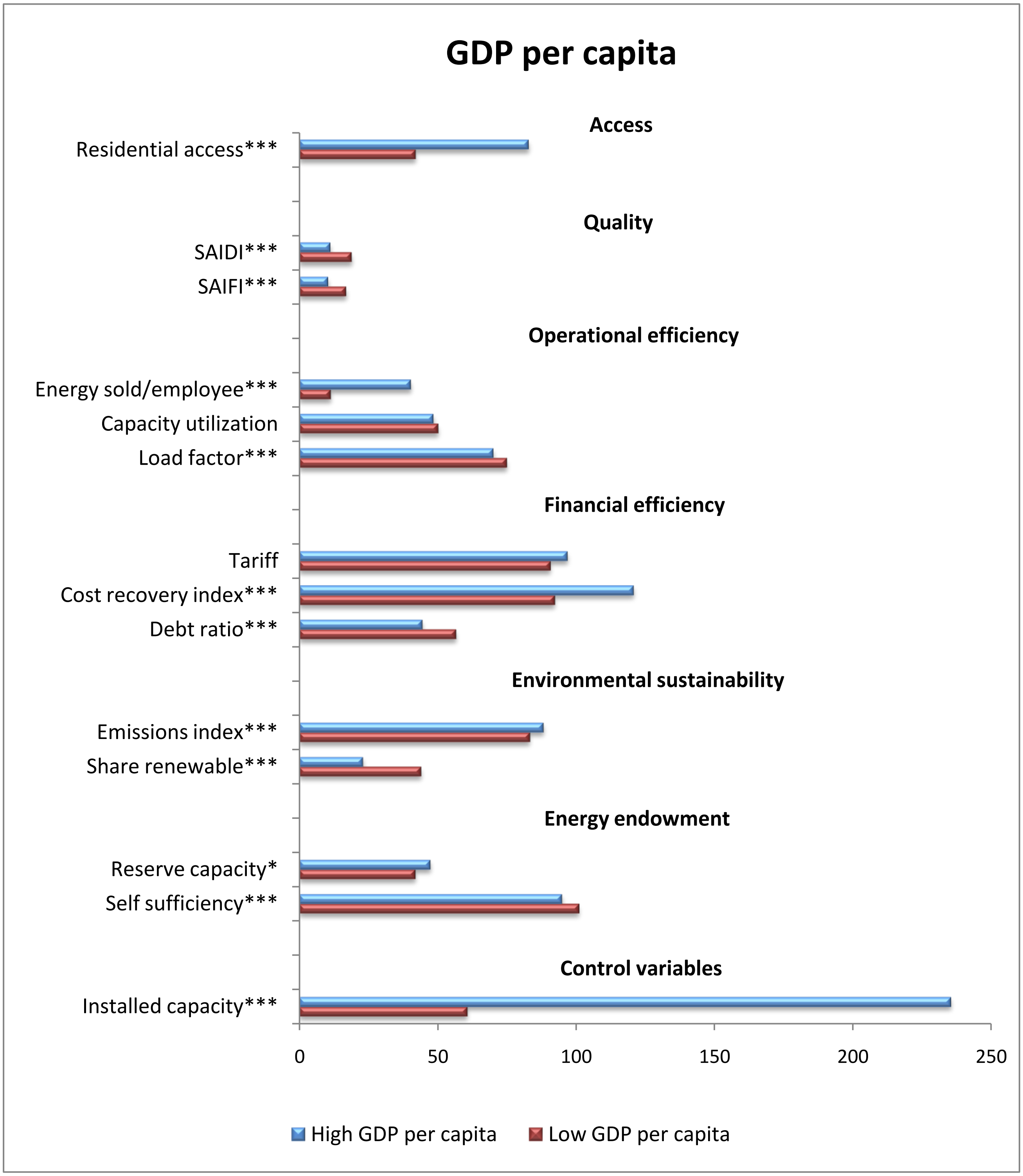
Note: The following adjustments were made to make the indicators fit in the same figure. Tariff ($US cent per MWh) instead. Emissions index (that is measured as a number from 0 to 1) was multiplied by 100. Energy sold per employee (measured in MWh per employee), Installed capacity (measured in MW), and GDP per capita (measured in $US) were divided by 100.

	High % of private ownership	Low % of private ownership	t
Residential access * (% population)**	76.1 (30.9)	52.7 (35.0)	-4.8
SAIDI	9.7 (8.2)	13.7 (20.2)	1.1
SAIFI*	11.7 (7.4)	14.1 (7.6)	1.3
Energy sold per employee**	18.7 (11.8)	26.3 (28.3)	1.8
Capacity utilization	51.5 (6.9)	52.2 (11.1)	.5
Load factor***	80.3 (9.5)	71.4 (8.5)	-4.5
Tariff***	99.8 (52.3)	83.7 (40.3)	-2.2
Cost recovery index**	100.7 (22.7)	87.1 (40.4)	-1.8
Debt ratio	47.0 (23.5)	49.9 (22.9)	.6
Emissions index***	83.3 (4.9)	88.3 (7.7)	5.0
Share renewable	28.0 (29.8)	29.8 (31.4)	.4
Reserve capacity***	54.4 (28.3)	33.6 (22.1)	-5.6
Self sufficiency***	102.8 (7.3)	95.2 (16.6)	-3.7
Installed capacity***	51.6 (56.48)	141.8 (174.46)	4.5
GDP per capita	86.9 (53.1)	80.5 (74.1)	-.7



Note: The following adjustments were made to make the indicators fit in the same figure. Tariff ($US cent per MWh) instead. Emissions index (that is measured as a number from 0 to 1) was multiplied by 100. Energy sold per employee (measured in MWh per employee), Installed capacity (measured in MW), and GDP per capita (measured in $US) were divided by 100.

	High installed capacity	Low installed capacity	t
Residential access * (% population)**	80.7 (18.8)	48.1 (36.4)	-9.2
SAIDI	13.6 (16.2)	14.5 (16.1)	.3
SAIFI**	11.6 (7.4)	15.6 (14.4)	1.8
Energy sold per employee***	46.5 (23.8)	12.3 (9.6)	-2.7
Capacity utilization***	46.6 (16.8)	51.1 (11.4)	3.1
Load factor***	74.6 (6.8)	70.6 (9.9)	-2.7
Tariff**	73.8 (42.8)	95.9 (93.5)	2.0
Cost recovery index	102.4 (71.4)	112.2 (53.9)	.9
Debt ratio	52.4 (15.8)	49.0 (27.8)	-.8
Emissions index**	83.9 (9.8)	86.6 (7.5)	2.9
Share renewable***	28.1 (27.8)	40.5 (34.8)	3.7
Reserve capacity	47.4 (23.1)	43.5 (30.2)	-1.0
Self sufficiency**	99.4 (6.8)	96.9 (17.2)	-1.6
GDP per capita***	99.0 (54.6)	57.3 (61.9)	-6.7



Note: The following adjustments were made to make the indicators fit in the same figure. Tariff ($US cent per MWh) instead. Emissions index (that is measured as a number from 0 to 1) was multiplied by 100. Energy sold per employee (measured in MWh per employee), Installed capacity (measured in MW), and GDP per capita (measured in $US) were divided by 100.

	High GDP per capita	Low GDP per capita	t
Residential access * (% population)**	83.0 (19.9)	40.8 (33.5)	-13.9
SAIDI***	11.4 (14.2)	19.1 (18.8)	2.6
SAIFI***	10.6 (7.1)	17.7 (14.2)	3.3
Energy sold per employee***	40.4 (25.9)	11.5 (9.3)	-11.3
Capacity utilization	48.6 (16.6)	49.9 (10.1)	.9
Load factor***	70.3 (6.5)	74.9 (10.9)	3.3
Tariff	98.1 (49.0)	59.7 (29.5)	-7.4
Cost recovery index***	120.9 (56.2)	84.6 (47.2)	-4.4
Debt ratio***	44.6 (18.5)	56.7 (27.6)	3.1
Emissions index***	88.3 (7.0)	83.2 (8.9)	-6.1
Share renewable***	23.2 (28.6)	44.1 (31.8)	7.6
Reserve capacity*	47.5 (47.5)	42.0 (33.5)	-1.5
Self sufficiency***	95.1 (15.8)	100.9 (11.6)	3.9
Installed capacity***	235.5 (240.3)	60.9 (73.3)	-9.9

Appendix 4
Cautionary note and sensitivity analysis

Multicollinearity

- Multicollinearity can represent a serious problem when estimating generalized linear models (as in the case of a Probit model). Multicollinearity is a statistical phenomenon in which two or more variables in a multiple regression model can be obtained as the linear combination of the other variables, which makes them highly correlated. In a nutshell, multicollinearity emerges when the explanatory variables are strongly linearly dependent. In such a case, the coefficient estimates may change erratically in response to small changes in the model or in the data. Even if multicollinearity does not reduce the predictive power or reliability of the model as a whole, it seriously influences calculations concerning individual predictors.[4]

- If multicollinearity is present, one should check for the so-called dummy trap; increase the dimension of the data set; remove one or more variables from the analysis (doing this may imply in some cases losing some explanatory power and biasing the coefficients of the remaining regressors, if those variables are relevant for the analysis); impose special structures.

- There are different possible tests to check for multicollinearity. Some of them are based on specific measures, such as the variance inflation factor and the condition index, but their interpretation is often heuristic. Here we prefer to use the standard F-test on regression coefficients, since it is the simplest to read and interpret. The test is based on the consideration that collinear variables tend to have insignificant coefficients, since every variable is able to explain a certain but not sufficient amount of the total sample variability. Hence, in case of multicollinearity, we can observe insignificant regression coefficients for the affected variables, but we reject the joint null hypothesis that those coefficients are all zero, indicating that in some way they have some explanatory power. This analysis is based on a simple F-test (i.e. a multivariate extension of the t-test).

- Our F-test tests show that multicollinearity is not present in our model (the null hypothesis of all insignificant coefficient being zero is not rejected), thus the not significant regressors can be simply removed from the analysis, increasing the overall power of the model and decreasing its complexity.

Endogeneity

- A possible criticism to our model is the likely presence of endogeneity, a quite common problem in econometric models. A variable is defined endogenous when there is a strong correlation between that variable and the error term. Intuitively, a loop of causality between the independent and dependent variables of a model leads to endogeneity. In more details,

[4] A high degree of multicollinearity may also occasion computer software packages to be unable to perform the matrix inversion, which is essential for computing the regression coefficients, making the results of that inversion inaccurate. It is indeed known that if two or more columns (rows) of a matrix are collinear, then the determinant of that matrix is 0 and inversion is not possible. Stata did not report any case of problems of the inversion of the matrix.

endogeneity can arise as a result of measurement errors, autocorrelated errors, simultaneity, omitted variables, and wrong sample selection.

- The main effect of endogeneity is that, in an OLS regression, the coefficients are biased. If there is no simultaneity, the estimates can still be consistent. In the worst case, this is the situation of our analysis.

- There are many methods to overcome endogeneity. Two of the most used ones are instrumental variables and the Heckman selection correction. Panel analysis can also be a good way to deal with endogeneity issues. In fact if the correlation structure that causes endogeneity is constant over time, a simple fixed effect model is able to deal with, possibly removing it from the analysis. This is due to the fact that, if the fixed effect model is the appropriate one, differencing (one of the possible tools used in fixed effect models) is able to remove constant structures from the data. However, if the correlation structure is not constant over time, other techniques, such as instrumental variables, are more suitable to treat endogeneity. If some endogeneity is present in our data/model, it is very likely due to a constant correlation structure, hence the panel analysis we have used should be sufficient to deal with it.

- Anyway, it is worth stressing that, in economics, everything tends to be endogenous. Therefore the use of some degree of moderation and wisdom is necessary when raising the point of endogeneity in a model.

- To partly control for endogeneity and multicollinearity among the different reform indicators we use a simple average index. The index takes the values 1 and 0 for countries that have implemented unbundling together with other reforms (reduction in market concentration, introduction of an autonomous regulator, and introduction of private ownership) and others that have not done so. However, this procedure imposes the restriction that each of the variables included in the index has the same proportionate impact on the dependent variable. This is a strong assumption, but at least our index is derived from direct observation rather than from impressionistic indicators that may not have an economic meaning (such as those derived by principal component analysis). That the core results are maintained even with combined aggregated reforms index suggests an underlying causal relationship and allow to control to some extent for endogeneity and multicollinearity. Even if they are not statistical artifacts arising from failures to address dynamics or endogeneity adequately, they may still be merely descriptions of a past set of events that cannot be applied to unbundling and future reform changes in sample countries—let alone to the implementation of unbundling and/or other sectoral reforms and/in other developing economies.