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How capacity mechanisms drive technology choice in power generation: The case of Colombia

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ABSTRACT

Colombia enacted its first legal framework for promoting alternative energies in 2001 and a second framework in 2014. Since the generation technology mix has not changed since 2000, there is a need to understand how regulation and market structure affect the adoption of technologies. In this paper we address the question of what has been the impact of the capacity mechanisms adopted during the 2000s on technology choices for power generation in Colombia. Our approach is to analyze the evolution of market structure and regulation. We found that regulatory uncertainty and low prices drove a surge of small hydro plants during the 2000s. During the 2010s, the new regulatory focus on reliability of supply has resulted in increased coal-fueled generation and large hydro. This increased reliance on hydro power can further delay the entry of renewable technologies and the diversification of the Colombian portfolio.
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1. Introduction

Technology choices for power generation determine to a large extent the structure of energy supply and have lasting impacts on the environment. During the last three decades, we have witnessed a shift away from coal to gas-fueled power generation, the introduction of renewable energy technologies, and recently in many countries a desire to move away from nuclear generation [1–3]. Some of these changes are motivated by environmental concerns, by technological uncertainty, economic changes, and perceived risk of nuclear power as well as ideological views, all of which play a role in establishing policy priorities.

The creation of power markets worldwide is the result of a broader energy policy aimed at increasing efficiency and attracting private investments – with the goal of satisfying a growing demand for electricity, particularly in the developing world [4]. In the early years of market reforms, increasing competition and efficiency in generation were the main issues by regulators and

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researchers. Bringing competition to the power market meant often unbundling utilities, breaking monopolies up, and creating commodity-like markets for electricity. Two decades later, future reliability is one of the main concerns in liberalized markets [5–9]. In fact, the International Energy Agency (IEA) and European Union (EU) estimate that EU countries need to invest Euro 1 trillion from 2012 to 2020 and a further Euro 3 trillion to 2050 to ensure adequate electricity capacity [8], despite some disagreements with these estimates [10]. Ensuring that such new investments are made in a timely manner is a challenge for power markets and it might be an opportunity for introducing alternative generation technologies.

In theory, a competitive market setting should give the right signals at the right time for investors to choose the best technology for expanding generating capacity. Power markets, however, are not perfectly competitive [11], future returns are highly uncertain [12] and investment decisions are constrained by environmental concerns, availability of appropriate generation technologies and the general future economic outlook [13]. As a result of the high uncertainty and the long lead times for new projects, it is common for power markets to observe cycles of over- and under-capacity margin [14]. Such fluctuations increase supply risk, and thus the objective of regulation is to reduce them. Achieving a long-term security of supply (resource adequacy) at a low cost is particularly challenging for developing countries that face increasing demand and need to expand access to energy [5–9,15].

While markets in different jurisdictions have different price-setting mechanisms, the most common mechanism is prices based on marginal costs. Marginal cost-pricing, however, does not offer sufficient incentives for adding new capacity and increasing long-term security of supply [16], a phenomenon known as the "missing money problem" [17]. Most markets solve it by using a separate, often complex, set of rules for calculating and allocating payments for capacity availability – known as capacity payments. The idea behind capacity payments is to recover capital costs that are not part of the market price, thus keeping enough capacity to satisfy demand at a given reliability level. Nowadays, there is a debate on whether capacity payments are needed, instead of relying on an energy-only market that rewards generating plants with scarcity rents [15,17,18]. Suppliers in an energy-only market bid prices instead of bidding their marginal cost. Price bids should include the capacity cost and they also increase during peak demand periods, when capacity is scarce. Many electricity markets use capacity payments or a related mechanism to increase the revenues of the generators and to incentivize their investment in new capacity. That is the case of Argentina, Brazil, Chile, Colombia, Perú, Spain, and the UK [15]. Alternatively, Australia, Alberta, ERCOT, and New Zealand have complete commodities markets for electricity and have implemented energy-only markets that have been successful so far [17].

The contribution of new capacity to the system's reliability depends on the size and timing of investments and varies widely across technologies. Wind technologies, for instance, have nameplate capacities that are between 60 and 70 percent higher than their annual output, and they only increase capacity margins when wind is available. In fact, a proper mix of technologies increases the reliability of supply. Therefore, regulators need to understand the logic of investment decisions and tailor the resource-adequacy mechanisms to each particular case.

To a great extent, the incentives and rules set by regulators drive technology choices by investors in a particular area, and the pace of the investment. The consequences of investment decisions are complex as new capacity takes from some months (e.g. Photo Voltaic (PV)), several years (e.g. Combined Cycle Gas Turbines (CCGT)) to a decade (e.g. big hydro) to come on-stream. Moreover, capacity is often added in large chunks and has a long life-time compared to other industries, making it more difficult to ensure that the right incentives are in place to achieve the right mix of technologies.

The aim of this paper is to illustrate how different regulatory regimes affect technology choices, using Colombia as a case study. Colombia is an interesting case as the incentives for adding capacity have been modified twice since deregulation, in an effort to adapt the regulation to shifting economic and market conditions. The first incentives (1996–2006) aimed at reducing the electricity system's vulnerability during dry periods. These incentives were modified in 2006 in order to provide signals for expansions of the system. While regulation has succeeded in securing supply during dry periods, the technology mix has remained basically unchanged since 2000. Furthermore, with the exception of small hydro plants, penetration of other renewable technologies is almost zero. In the next sections we examine how capacity mechanisms and the structure of the market have influenced technology choices for power generation in Colombia.

This paper is organized as follows: Section 2 makes a brief description of the Colombian power system, including the capacity before deregulation and explains the events that led to deregulation. Section 3 describes and discusses the resource adequacy mechanisms used in Colombia, and their impact on the generation mix, including capacity mechanisms' implications for renewable energy. Section 4 presents the main insights and conclusions from the previous analysis.

2. Overview of the Colombian power system

Seasonal variations of power demand in Colombia are relatively small, and high capacity margins are maintained as a reliability strategy. Because the share of hydro generating capacity is larger than 65%, the Colombian power system is vulnerable to weather changes such as the prolonged and intense droughts caused by the macroclimatic phenomena of "El Niño South Oscillation" (ENSO). The interconnected power system provides electricity to 94.6% of the population [19], with high quality standards. Table 1 summarizes the main indicators of Colombia's macroeconomic condition and power system. Hydro power dominates the technology

Table 1
Macro-economic and electricity industry indicators in Colombia.

Demographic and economic indicators		**Electricity prices ($US/kW h) 2012**[a]	
Population (est. Jan. 2015)[b]	47,965,803	Residential	0.2
GDP (ppp) Billions US$ (est. 2013)[c]	526.5	Industrial	0.22
GDP per capita (ppp) 2013 est.[c]	11,100	Commercial	0.16
		Market structure	Bid based
Installed generation capacity (MW), Dec. 31 2013[d]		**Electricity demand profile (2012)**[e]	
Hydro	9875	Industry	31%
Thermal	4598	Transport	0%
Wind	20	Residential	41%
Co-generation	66	Commerce and public	24%
Total	14559	Agricultural/Forestry/fishing	4%
Energy intensity[e]		**Electricity demand growth**[e]	
TPES/pop (toe/capita)	0.66	Average 2004–2008	3.0%
TPES/GDP (toe/000 2005 USD)	0.16	Average 2008–2012	4.5%

[a] [24].
[b] [22].
[c] [21].
[d] [20].
[e] [23].

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