Institutional and technological lock-in in the choice of power generation portfolio: the Brazilian case

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The development of renewable technologies for power generation is a relatively recent trend. Some of these technologies, as solar photovoltaic power generation, have different organizational features with respect to traditional generation technologies. The potential of the new technologies to be actually placed in the market does not depend just on technological changes but also in the institutional evolution. Technologies impact on the choice of the coordination mechanism. The coordination mechanism is in turn not neutral regarding technological choices. The current Brazilian institutional framework to coordinate the electricity industry was explained by the dominant role of hydropower in the generation portfolio. The need to coordinate large investments which were interconnected by the river flow justified the choice of a centralized institutional framework to plan, to finance and to choose new technologies. As a consequence, we observe that the development of decentralized forms of power generation, as solar photovoltaic, have been completely overlooked in Brazil. We propose a co-evolutionary analysis of the Brazilian case, to analyze long-term dynamics. We show that power sectors evolve within a path defined by a tight interrelation between the institutional setting and the technological environment. One of the most important features of our characterization is the existence of intertwined technological and institutional path-dependence. Therefore, implementing new technologies efficiently will require the adoption of policies that alleviate situations in which the generation portfolio is locked in to incumbent technologies.

Key words: Co-evolution; Institutional evolution; Path-dependence; Electricity.

Extended abstract

This paper re-examines the design of mechanisms to promote renewable energies. The starting point is that renewable power generation should not be seen just as a clean technology but as a new technology. The policies to promote it should not just tackle the challenges regarding the inclusion of externalities but also the challenges regarding the change of the technological paradigm. To that end, we relax the hypothesis that power sectors follow equilibrium dynamics (hence we consider boundedly rational agents) in order to represent in more detail the long-term dynamics of the power sector in Brazil. We propose a co-evolutionary framework to analyze such long-term dynamics, showing that power sectors evolve within a path defined by a tight interrelation between the institutional setting and the technological environment. One of the most important features of our characterization is the existence of intertwined technological and institutional path-dependence. Therefore, implementing new technologies efficiently will require the adoption of policies that alleviate situations in which the generation portfolio is locked into incumbent technologies. We finally derive some policy implications. The characterization of the innovation process shows that relatively simple market signals (as CO_2 prices) are likely not enough to facilitate the adoption of new generation technologies. Consequently, energy policies aimed to compensate for “static” market failures as CO_2 externalities will not be able to avoid barriers for the adoption of new technologies in the long run, as they will incentivize the generation portfolio to continue locked in to incumbent technologies.

We will set up a methodology to analyze policies in the context of a transition to new technologies. Our standpoint is that the transition is not necessarily associated with low-carbon objectives but with the need to invest in new generation equipment. In that view, the Brazilian system faces the choice between investing in incumbent technologies (a wait-and-see strategy with respect to other systems) and developing new technologies (possibly low-carbon ones). From that standpoint, our analysis will be close to the ideas developed in (Unruh, 2000) or (Nill and Kemp, 2009).

More often than not, this question is approached from a static point of view. Our view builds on the idea that technological and institutional frames are interrelated. Put differently, the technological environment affects the institutional environment and the other way around. In that view, our approach builds on the framework developed in (Foxon, 2011). In this paper, we tackle the analysis of power systems dynamics from an evolutionary standpoint. Our reasoning builds on the idea that the agents involved in any economic activity, and hence those involved in the power sector activities, cannot be described by static decision-making models. Instead, we think of those decisions as consequences of dynamic processes.

In that view, there are two elementary dimensions to understand the long-term dynamics of the power sector as an evolutionary process. On the one hand, (Nelson and Winter, 1982) argues that technological evolution

happen within economic and social environments, which in turn are affected by the evolution of technologies.

On the other hand, understanding the long-term dynamics of the power sector requires relying on economic theories that relax the equilibrium hypothesis, many of which can be traced back to (Schumpeter, 1942). From our point of view, one of the most relevant views of the previous theories is that economic players do not behave as solving profit-maximization problems. Instead, they follow ‘routines’ that result in satisfactory profits, not necessarily maximum profits. Those routines are only modified when the previous outcomes stop being satisfactory. This is the view of (Nelson and Winter, 1982), which is closely related to the Simon’s description of rationality, (Simon, 1959). Using this background one can think that the organization of power industries (companies and planners) establishes routines and a group of elements that are considered in their analysis. And as long as the system have no important break down, there are no strong incentives to look outside the box of variables and technologies. Institutions also change, as has been underlined by (North, 1990), among others. The way they evolve, however, depends on a set of elements as inter-institutional competition and hierarchy, as described by (Ostrom, 2009).

In order to deal with these economic characteristics, we developed a simulation tool that aims to analysis potential policies that may be a tool lead with the current technological lock in context. As shown by (Arthur, 1994), the technological lock-in is related to the existence of increasing return to scale. One may observe them, besides the existence of scale economies, in learning effects, adaptive expectations and network economies –understood as advantages that appear when several players adopt the same technology. Those increasing returns to scale would lead to technological lock-ins. On the other hand, the institutional lock-in refers to a situation where certain institutional setting comes with increasing returns. This concept builds on (North, 1990), who shows that the same reasoning applied to technologies can be applied to institutions: there are also economies of scale (“fixed costs” related to setting up a new institution), learning effects, adaptive expectations and network economies. Consequently, they will be also subject to the possibility of lock-ins.

The electricity sector is locked in to incumbent technologies. In the literature, this problem is often associated with the fact that incumbent technologies are fossil-fuel based, but we do not impose that characteristics. In fact, the most important electricity production technology in Brazil is hydro power, which is not based on fossil fuels.

From the analysis above, we identify at least one main objective of energy policies: to help to lock out the development of new technologies. Following (Foxon, 2002), policies and mechanisms can be classified under the following broad headers:

- R&D policies: the cased for the need of R&D support for new technologies is widely accepted, as incumbent technologies have benefitted from large amounts of R&D aids over the years.

- Mechanisms to facilitate insertion: The idea behind this mechanisms is to create niche markets where new technologies can benefit from learning. In this context, measures to avoid picking the winner must be adopted. Additionally, one may add long-term signals to the market, e.g. in the form of outcome-based targets.
- Financial incentives: costs of new technologies decline over time, as promoters acquire experience on investment and operation. Hence, in early stages when learning curves are steep, each investment implies the direct benefit (we assume the deployment of the technology is social-welfare-improving) and an indirect benefit associated with the previous cost reductions, which will be enjoyed in future investments.

We propose to use a system dynamics model to understand the evolution, i.e. possible pathways, of the Brazilian sector, see for instance (Forrester, 1968). This understanding is aimed at aiding decision-making in the design of the generation portfolio of the Brazilian system.

That decision-making process has two main dimensions from the viewpoint of public administration. On the one hand, the definition of the institutional framework, in a context of stress in the innovation system, is crucial for the development of new technologies. On the other, understanding pathways for the evolution of the power sector is instrumental in the definition of sensible energy policies.

In this section, we propose a methodology to analyze the effects of different policies to promote renewable technologies. We consider them in the context of the decision-making process of the power sector, in order to understand their interaction with the rest of the institutions that coordinate the electricity sector. The basic scheme of the framework is represented in Figure 1. Note that we have included in the framework the sets of measures to facilitate technology innovation except R&D policies.

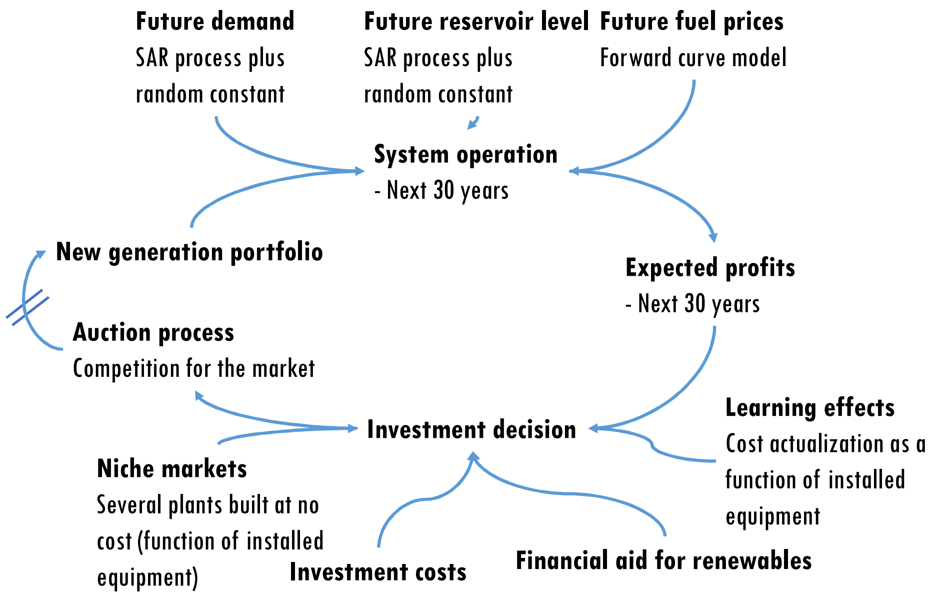

Figure 1. Framework to analyze renewable policies.

Our simulation of the Brazilian system shows that in most of the cases, financial aids for new technologies, for instance in the form of renewable support, is not enough to ensure the insertion of those new technologies. The creation of strategic niche markets is instrumental in the development of a new generation portfolio.

This is consistent with an analysis of the recent past policies in Brazil concerning wind power production. Dedicated mechanisms, namely ensuring a certain amount of wind power production in the auction process, have been extensively identified as a source of the increase of competitiveness of this technology.

On the other hand, as shown in our simulation, the mechanism chosen to implement new technology production matters. Applying the same idea to solar power production may create effective barriers to new technologies based on distributed generation.

We identify the co-evolution of technological and institutional environments in the power sector in order to describe its dynamics. Understanding these dynamics is necessary to design the adequate institutions and policies. Consequently, energy policies aimed to compensate for "static" market failures will create barriers for the adoption of new technologies in the long run, as they will incentivize the generation portfolio to continue locked in to incumbent technologies.

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