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The role of regulatory learning in energy transition: The case of solar PV in Brazil

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ABSTRACT

An important problem that has attracted significant amount of attention within the context of energy transitions is the carbon lock-in: a situation in which energy systems are locked-in to high carbon technologies through a path-dependent process. Several measures to avoid the carbon lock-in involve technology-specific measures, which in turn implies that those measures may result in an energy system locked-in to certain low carbon technologies. We consider that the Brazilian system needs policies to escape the carbon lock in, which are based on providing incentives to low carbon technologies. We develop an analytical framework to analyze the role of regulatory institutions in the possible lock-in to utility-scale photovoltaic, in the sense that they create barriers to the adoption of distributed-generation photovoltaic. We show that the definition of a process to adapt the institutional framework in a context of stress in the innovation system is crucial for the adoption of new technologies. Applying our framework to the Brazilian power sector, we observe that only when regulators consider the possibility that the system is locked-in to centralized production technologies (and not when they just consider the carbon lock-in) they manage to eliminate barriers to distributed generation based on solar PV.

1. Introduction

The electricity industry has taken center stage in the transitions to economies based on low carbon technologies. In this paper, we are concerned with the challenge of designing measures to facilitate transitions to low carbon electricity systems. The adopted measures are the result of a framework that establishes, among other dimensions, the objective of the particular policy –along the lines of the theory of economic policy, (Tinbergen, 1952). One controversial aspect regarding the definitions of policy objectives within the energy transitions context is whether policies should be technology-specific. The discussion may be motivated from the fact that different policies respond to different objectives, (Gawel et al., 2017). Thus, depending on whether technology evolution is considered or not, the importance of industrial and technology policies have more or less importance in the design of policies to facilitate energy transitions.

This paper is framed by an evolutionary view of both technological and institutional development, along the lines of (Foxon, 2011). This co-evolutionary thinking deals with the fact that, on the one hand, policy objectives might change when technology practice changes. On the other hand, if policy objectives are too rigid, they may create circumstances under which technologies might be in the market even though they are inferior to other technologies. We will term this situation as lock-in, (Arthur, 1989). One of the less explored consequences of the co-evolutionary framework is that policies are rarely implemented by external, fully rational rule-makers. That is, rule-makers do not decide using deductive, rational reasoning but they use inductive reasoning instead, (Arthur, 1994). Specifically, we represent that rule-makers, in a context of significant complexity, understand reality through simplified models that are then used to perform deductions. Such simplified models may be interpreted as beliefs. Rule-makers also obtain feedback from the complex environment, which allows them to modify decisions according to their beliefs (their simplified models). In order to develop an analytical framework to analyze energy transitions that takes account of the previous situation, we use the Institutional Analysis and Development (IAD) framework, (Ostrom, 2009). In the IAD, the main drivers to change rules are the ‘evaluative criteria’ applied to outcomes. We connect the idea of evaluative criteria to rule-makers’ beliefs in order to define how institutions change.

Our study is placed within the context of energy transitions, which can be understood as processes to make energy systems less dominated by fossil-fuel technologies. In order to understand potential paths for

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transitions to low carbon energy systems, it is necessary to analyze the design of energy policies, which are based on specific assumptions on the behavior of the power industry.

One very common view is identifying energy transitions with an externality problem associated with climate change, (Pérez-Arriaga and Linares, 2008). In this context, the objective is to design mechanisms that internalize the externality, hence the reasoning suggests the use of technology-neutral schemes, (European Commission, 2014a). In that context, energy policies are often analyzed in terms of just prices and/or installed capacities, see for instance (Haas et al., 2011) for a historical perspective of support mechanisms, (del Río and Linares, 2014) for an analysis of auction-based methods, or (Lopez-Polo et al., 2012) for a specific application to photovoltaics.

The previous "environmental-externality" point of view may be complemented by the consideration of innovation externalities, i.e. the positive externalities created by innovation, (Jaffe et al., 2005). This makes less obvious the case for technology-neutral policies, which likely motivates that the European Commission also finds justification for technology-specific schemes, e.g. (European Commission, 2014b). This point of view may be identified with "technology market failures", (Gawel et al., 2017).

The two previous descriptions of the transition problem are based on identifying externalities, which implies a static representation of the industry, (Witt, 1996). Evolutionary economics depart from the externality-based reasoning and consider an out-of-equilibrium process[1] to represent energy transitions, see for instance (Foxon, 2011) or (Nill and Kemp, 2009). Our paper is placed within this view, as regulatory learning is better understood as a dynamic process. The evolutionary standpoint implies taking into account that one groups very different policies under the header "policies to incentivize renewable energy sources". This is a consequence of the fact that not all policies to promote renewable production are designed to fulfill the same objective. To see this, one may consider the "complex value" approach for business model analyses introduced in (Hall and Roelich, 2016), where motivations such as competitiveness, self-governance, environmental concerns, reduction of fuel poverty, etc. are identified as drivers for actors in the energy system. Another recent example can be found in (Bauwens, 2016), where motives for investment in renewable energy technologies in energy communities are analyzed in depth.

Considering this complex interaction among actors require considering the institutional dimension of the problem. In this regard, (Jacobsson and Lauber, 2006) explains the institutional dynamics behind the German introduction of low carbon technologies. In particular, regulatory frameworks are pointed out as a central driver of the transition. Recently, (Iychettira et al., 2017) propose an institutional analysis to simulate the construction of renewable policies using agent-based models. Hence, representing technological dynamics together with complex policy objectives highlights the need for a multi-level description of the transition process. In this paper, we will describe energy industries as large systems with multi-layered interactions, where technological evolution (including innovation policies) are relevant to understand industry dynamics. To that end, we propose to use a co-evolutionary framework, (Foxon, 2011). This has been also the choice of other recent applications to energy industry studies. (Bolton and Foxon, 2013) use co-evolutionary thinking to analyze business models at the retail level in GB, pointing at the fact that some regulatory actions (consumers' right to switch supplier) constrain the innovation in both consumers' profiles and low carbon generation options. Along the same lines, (Giordano and Fulli, 2012) shows that smart meters and electric vehicles may facilitate the development of new distribution business models by creating opportunities to capture new complex values in the entire system.

The previous literature shows the importance of the design of the regulatory framework in the dynamics of the energy industry. From this point of view, we complement the literature by analyzing the dynamics associated with rule making. Specifically, we highlight one element that has received relatively little attention: the process to change rules-in-use[2] should be a robust one in order to allow proper institutional learning. To that end, we build a framework that represents the dynamics of institutional adaptation, where rule-makers will adapt, after observing industry outcomes, according to their assessment of whether outcomes match their objectives (evaluative criteria).

In summary, in order to understand the coevolution between institutions and technology in the energy industry, it is necessary to consider that:

- Institutions interact with technology
- Different layers of the decision-making process interact among them
- Policy implementation is done through multiple layers that include regulation

We apply the previous reasoning to the analysis of the Brazilian electricity system. The base case in our study is the view that the Brazilian system needs policies to escape the carbon lock in. Specifically, the focus of our study is to investigate the mechanisms by which regulatory institutions may lock in the system to utility-scale technologies. From the technological point of view, the most studied problem is the carbon lock in, (Unruh, 2000): a situation in which energy systems are locked in to high carbon technologies through a path-dependent process. But several measures to avoid the carbon lock-in imply technology-specific measures, (Nill and Kemp, 2009), which in turn may lock in the energy system to certain low carbon technologies.

Such policies are based on giving incentives (regardless the particular mechanism to implement the incentives) to low carbon technologies. In order to understand the potential for lock in, it is important to consider that Latin American countries have been examples of significantly centralized implementations of market arrangements, (Hammons et al., 2011).[3] Most of the justifications for those centralized market arrangements imply the idea of centralized generation of electricity through large power plants. At the same time, during the last years, the optimal technical solution to produce electricity has become less clear. In particular, solutions to produce electricity in a decentralized manner have become increasingly attractive. The question that arises in that context can be posed as: can this decentralized technology enter into centralized market arrangements, even if these market arrangements contain policies to facilitate investment in low carbon technologies? The answer may depend on the particular rules governing the sector.

We restrict our attention to the case of solar PV in Brazil, where the institutional framework for power generation (based on a centralized market design) contains barriers for distributed generation to enter the market. If rule-makers do not adapt to changing technologies, solar generation will (potentially) be locked in to utility-scale PV technologies precluding the entrance of distributed solar PV. To that end, we develop a system dynamics framework along the lines of (Forrester, 1968) to model the Brazilian electricity sector. The analysis of regulators' response is based on the identification of different evaluative criteria (different policy objectives) that are used to analyze the need for adaptation. That is, if the outcome of market players' investment decisions does not fulfill the policy objective they sought, they will change the rules to improve the outcome. We consider three types of policy objectives. In the first case regulators observe only that

[1] We will review the economics behind this point of view in section 3.1.

[2] (Crawford and Ostrom, 1995) provides a thorough analysis on the definition of rules. According to it, we use the definition of rules as prescriptions of what players involved "must" do, "must not" do, or "may" do, and the associated sanctions in case rules are not followed.

[3] Note that the trend currently observed in Europe, and to some extent in the US, is to implement more centralized solutions.