POLICY MIXES FOR ENERGY TRANSITIONS

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# Overview

Climate change is a phenomenon directly linked to man-made increases in greenhouse gases emissions (IPCC 2022a; 2022b). We as a society must take action and develop means to mitigate climate change and its effects. The energy sector is one of the top emitters of greenhouse gases worldwide. Electricity systems are a relevant portion of the energy sector. One way to mitigate climate change is to transition to low-carbon electricity mixes through the increase of renewables and decline of fossil-fuel electricity generation. Such solution is being attempted by both developed (e.g. EU countries) and developing countries (IEA 2016; IEA and IRENA 2017; EPE 2017). This article focuses on energy transitions towards low-carbon electricity systems in developing countries using mixes of policies.

**Methods**

We aim to further analyze the effects of financial constraints of such developing countries on transition processes, as well as to analyze the effects of policy interactions in such context. From a methodological standpoint we start from Ostrom’s Institutional Analysis Development (IAD) Framework (Ostrom 2005; 2011). The IAD framework focuses on the interactions and outcomes of agents in a situation that is bounded by multiple rules. Such interactions occur in a computational simulation named Technology, Finance and Energy model (TeFE), i.e., we use an agent based model to simulate interactions between agents (de Marchi and Page 2014; Lamperti et al. 2018; Dosi, Fagiolo, and Roventini 2010). Such simulated agents are: technology producers, responsible for producing electricity generation assets; energy providers, that acquire such assets in order to produce electricity; an energy policy maker, responsible for the auction mechanism; a technology policy maker, responsible for giving incentives to technology producers; and a development bank, responsible for financing the acquisition of electricity generation assets by energy producers with subsidized interest rates. Our model consists of two classes of industry agents and three classes of policy makers. On the industry side, we consider energy providers and technology producers. Technology producers invest in productive capacity or into R\&D and manufacture energy provision assets, focusing on either wind or solar technologies. Energy providers acquire assets from technology producers in order to provide energy. The Energy Policy maker promotes auctions with long-term power purchase agreements, reducing cash flow risk of investments. The Technology Policy maker increases the cash flow of technology producers with incentives. The Development bank finances the acquisition of renewable power plants by energy providers. All agents pursue a satisficing heuristic, following (Simon 1959): private agents attempt to catch up when lagging behind but will accommodate themselves when in front of competition. Public agents increase policy effort (mainly budget) when system results’ steer away from policy goals. We consider three types of policy makers’ goals regarding renewables: to foster their use in relation to carbon-based sources; to focus on the development of their local productive capacity; and to focus on the development of R\&D capabilities. Different policy makers may have similar or different goals, which increases or reduces the congruity of the policy mix. Agents in the IAD framework are also able to evaluate outcomes and adapt. Interactions occur in a context in which path dependence, sunk costs and innovation are present, which highlights the relevance of technology adoption.

# Results

The results from model show that a policy mix in which multiple policies are combined leads to energy transitions that are understood as better by both policy makers and private entities, i.e., energy transitions that yield higher profits and better achieve policy goals. Moreover, policy mixes with multiple policies achieve such status faster than scenarios with just one policy in place.

**Conclusions**

In non-central economies, combination of policies through policy mixes produce non-trivial effects regarding both the level and speed of energy transitions.

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