Characterizing the policy mix and its impact on eco-innovation in energy-efficient technologies

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Extended Abstract

The analysis of how different technological domains broadly classified into the eco-innovation field have evolved during last years is gathering growing attention both at the academic and policy level. The current debate has adopted distinguished analytical perspectives in order to better understand the dynamics, characteristics, and determinants of eco-innovation (Arundel and Kemp, 2011; Arundel *et al*., 2011; Beise and Rennings, 2005; Berkhout, 2011; Borghesi et al., 2013; Costantini et al., 2015; Kemp and Oltra, 2011; Markardet al., 2012; OECD, 2011; van der Bergh et al., 2007; Wagner, 2007).These studies suggest that it is a variety of factors that drive eco-innovation but also highlighted the primary role played by public policies (environmental regulation, energy and technology policies)that are increasingly used to foster the rate of introduction and the diffusion of new environmental technologies to meet sustainable development goals(Del Rìo, 2009a;Horbach et al., 2012;Johnstoneet al., 2010; Mowery et al., 2010; Newell, 2010).

The bulk of previous literature has focussed the attention on the impact of single (though different) policy instruments mainly belonging to the two broad categories of demand-pull and supply-push instruments (Bergek and Berggren, 2014; Horbach *et al*., 2012; Kemp and Pontoglio, 2011; Peters *et al*., 2012; Rennings, 2000). Recentempirical contributions have demonstrated that these instruments have differentiated impacts on the diverse types of innovative activities such as those related to the introduction of incremental or radical innovations (Nemet, 2009) or associated with technological exploitation or exploration activities (Hoppmannet al., 2013; Costantini et al., 2015).However, there is growing interest in understanding the role played by the different combinations of the available policy instruments in stimulating and directing technical change. In particular, the literature is recently focusing on the role of policy mix and the consequences of policy interactions and interdependencies between different policy instruments (Flanagan *et al*., 2011, Rogge and Reichardt, 2013). In this respect, policy mix studies applied to eco-innovation domains tend to be limited in examining the effects of the mix design and instrument interactions (Del Río and Hernández, 2007; IEA, 2011a,b) and further empirical analysis is required in order to assess the contribution of policy instruments interaction in a systemic view (Coenen and

DíazLópez, 2010).

Following recent contributions that have explored the possibility to analyse the impact on eco-innovations of the policy mix and its characteristics by adopting detailed case studies or firm level surveys (Reichardt and Rogge, 2014; Mattes et al., 2014), we here propose a quantitative analysis based on a large sample of OECD countries aimed at measuring some relevant characteristics of the policy mix and at quantifying through panel data econometrics their impact on innovation activities. In doing so we contribute the literature by developing a characterization of the policy mix that triesto be at the same time informative and measurable, in order to analyse the innovation effects not only of policy mix elements but also of their characteristics, thus deriving new policy insights on how to designpolicy mix in order to foster the development of environmentally friendly technologies.

Such an analytical perspective is applied to the case of Energy Efficiency (EE) technological domain, which appears to be particularly relevant as it is characterized by the interplay of a wide range of agents and policy instruments involved, acting in different directions and with different objectives. As a matter of fact, the pervasiveness of energy consumption in the whole socio-economic context (from private consumers to the large scale manufacturing production) confers to this technological domain some specific features which should carefully investigated when a complex policy strategy is designed (Costantini and Mazzanti, 2012).The complexity of this domain deserves a specific effort in developing an appropriate analytic framework in order to capture the large number of linkages influencing the dynamic pattern of technological activities (Del Rìo and Hernandez, 2007; Flora*et al*., 2011). To this purpose,our approach aims at complementing standard policy innovation inducement analyses with a deeper investigation upon how the characteristics of the policy mix influence the technological trajectories in such domain.

The analysis shows that the level of coordination and coherence across the different policy instruments adopted at the domestic level is crucial. The greater the complexity of the objective of the policy mix, the larger the range of instruments necessary to be implemented in a systemic approach. In the energy efficiency of the residential sector, a larger coherence of the whole policy settings, *ceteris paribus*, has a positive influence on the innovation dynamics. When instruments are coherent, showing absence of contradictions and synergies among the different policy elements, the whole innovation system reacts positively to a lower uncertainty and reduced risks provoked by the potential conflicts arising when the complex policy mix is not coherent.

The the paper is organised as follows. Section 2 provides a literature review on policy inducement effects in eco-innovation and most recent methodological development in the analysis of policy mix strategies. Section 3 describes the proposed characterization of the policy mix in the case of EE technologies, while Section 4 lays out the research hypotheses and the econometric strategy. Section 5 presents the model results on the impact of the characteristics of the policy mix on eco-innovation in EE technologies. Finally, Section 5 summarizes the main insights emerging from the

study highlights the policy implications and outlines possible further research lines.