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HOW DOES GREEN TAX IMPACT ON ECO-INNOVATION IN THE UNITED STATES?

Abstract. The paper aims at analysing the relationship between environmental taxation (at national level) and innovation performance in the biofuel industry in the United States. Green innovation is currently perceived as a critical field for policy makers to enhance the necessary shift to a resource-efficient, low-carbon economy, but it is seldom investigated or specifically targeted in the innovation literature, and many of its specific attributes fail to be taken into account. Moreover, it is important to understand the mechanisms linking public policies and innovation incentives in order to inform policy makers on the possible consequences of adopting alternative policy mixes (Del Rio González, 2009). Governments, indeed, can either support technology development (supply push) or create new markets (demand pull) for environmental technologies (Horbach et al., 2012; Peters et al., 2012; Norberg-Bohm, 2000) e.g. by imposing a carbon tax. The main goal of this study is precisely to understand the strength of the relationship between this demand-pull policy-instrument and the innovation performance in a specific field of research, the biofuel, which is highly dependent on environmental regulations.

Keywords: eco-innovation, carbon tax, United States.

1. Theoretical framework

Green innovation (or eco-innovation) is largely acknowledged as a relevant field of investigation to address the interactions and the effects of different policy instruments with respect to the dynamics of innovation (Ambec et al, 2013). Eco-innovation has been defined by Kemp and Pearson (2007, p. 7) within the project "Measuring Eco Innovation" as "the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental

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risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives". Relevant environmental policy instruments related to eco-innovations are conventionally classified in the two broad categories of demand-pull and technology-push instruments (e.g. Horbach et al., 2012; Peters et al., 2012; Rennings, 2000): the formers entail the stimulation of technological innovations by providing publicly-funded R&D programs, the latters involve the creation of a market for emerging environmental technologies and include environmental regulations, regulation or deregulation of fuels and electric utilities, environmental taxation and subsidies for specific technologies (Norberg-Bohm, 2000). Both kinds of instruments have been found to be relevant in spurring innovation in environmental technologies, though they have proved to determine a differentiated impact with respect to two specific dimensions: (1) the incremental or radical nature of innovation (Nemet, 2009), (2) the exploitation of available technological knowledge vs. the exploration of new technological opportunities (Hoppmann et al., 2013). The trade-offs occurring within these two dimensions can be identified in terms of the capacity of the firm to activate profits in the short or in the long run and, consequently, the rate of survival in the market. Many scholars convincingly proved (Hoppmann et al., 2013; Nemet, 2009) that demand-pull policies might not be appropriate to stimulate non-incremental innovation; therefore, a policy mix designed with a prevalent weight of these policies may reduce the incentives for firm to invest in exploration activities. More in detail, demand-pull policies "create an incentive for firms pursuing more mature technologies to shift their balance between exploitation and exploration toward exploitation" (Hoppmann et al., 2013, p. 989), as it turns out to happen in the renewable energy sector where most of the innovative efforts focus on the mature technologies for power generation (Costantini and Crespi, 2013). Thus, firms engaging with less mature technologies cannot benefit from the potentials of exploitative learning to the same extent as those firms focusing on more mature technologies and may be consequently prevented to enter or survive in the market.

On the supply-technology side, the role of public policy in shaping the pace of innovation in environmental technologies is also important (Costantini and Crespi, 2013), since R&D policies are universally acknowledged as a major driver of eco-innovation (OECD, 2008) and they are better suited to spur technology exploration activities. For instance, advanced generation biofuels originate from science-based technologies and require technological exploration activities, so technology-push instruments are of crucial importance for their development (Hoekman, 2009; Panoutsou et al., 2013). However, a pure R&D-driven strategy can be ineffective in the absence of market formation activities as it forms a critical barrier to the development of advanced generation technologies (Hekkert et al., 2007; Suurs and Hekkert, 2009). Therefore, it is important to understand the mechanisms linking public policies and innovation incentives in order to inform policy makers on the possible consequences of adopting alternative policy mixes in terms of the balance between demand-pull or technology-push forces (Del Rio González, 2009; Costantini and Crespi, 2013), thus maximising the dynamics of innovation in general and, more specifically, those of radical innovation.

Within demand-pull policies designed to enlarge the markets for new environmental technologies, it is possible to distinguish between quantity-based (such as quotas and targets) and price-based support policies (such as feed in tariffs and tax exemptions). While the formers might determine declining innovation incentives when the technological standards tend to become nonbinding (Costantini and Crespi, 2013), the latters allow producer's surplus to increase with technical progress (Jaffe et al., 1995) and provide a permanent incentive to introduce innovations.

2. Analytical framework

This contribution focuses on a specific price-based policy, i.e. the carbon tax, with the aim of identifying the pivotal role played by this kind of instrument as a driver of environmental innovation in the biofuel industry, which has been specifically targeted with respect to the European countries (Costantini and Crespi, 2013) whereas a direct assessment of the US case is still missing. The purpose is to examine the impact of environmental taxation on green patent activity, within the biofuel industry, in the United States during the period 2004-2007

Methodologically, the role of environmental policies in fostering environmental technological change has been analysed with either qualitative or quantitative (econometric) approaches. Though they both have advantages and drawbacks, they allow drawing distinctive insights and should be considered as complements. More in detail, micro-econometric methods (most notably multinomial logit and probit models) have proven useful to analyse why firms choose a specific type of environmental technologies and the influence of external factors on this decision. Costantini and Crespi (2013) adopted, in particular, a Poisson Regression Model (PRM), which is a kind of econometric model that is more useful in dealing with count variables (nonnegative integer values), like patents. Nevertheless, micro-econometric models suffer from a number of problems. Firstly, they use cross-section that cannot give direct evidence of the dynamics of innovation/adoption decisions by firms, whereas panel data have generally proved more suitable for this purpose (though they are seldom available). Moreover, there's often some endogeneity in the explanatory variables used, thus determining biased estimations of the parameters (Mazzanti and Zoboli, 2006).

Regarding the data, many empirical contributions estimate the drivers of eco-innovation using patent data (Johnstone et al., 2010; Peters et al. 2012; Costantini and Crespi, 2013), which contain rich information about the technological field of the underlying innovation, the inventors and the relied patents. Nevertheless, the use of patent data as a measure of innovation is characterized by some limitations. As largely documented, patents cover only a part of the innovation output (as firms may prefer alternative ways to protect their inventions) and patenting is a common practice only in some technological fields. Moreover, patent data cannot take into account the whole phase of adoption of innovations, whereby the economic potentiality of innovations is usually tested. Still, patents could represent an objective and viable alternative to measure eco-innovation, as far as they are publicly available and they cover long time spans. For the purpose of this project, preference will be given to data on eco-patents to be collected mostly from OECD REGPAT and European Patent Office (EPO) databases. In order to properly identify patents related to eco-innovations, relevant sources of information are provided by the OECD project on "Environmental Policy and Technological Innovation" and by World Intellectual Property Organization (WIPO), with regard to the classifications identified under the "IPC Green Inventory" program, launched in 2010.

The main hypothesis underlying the analysis is that demand-pull policy instruments, in terms of carbon taxation, determine higher levels of biofuel-related patent activity. I made use of the total number of patent applications related to the biofuel industry in the period 2004-2007 in the United States as a proxy to estimate the level of innovation activity and I deployed the overall environmental tax revenues as the main regressor to underpin the role played by policy instruments in fostering innovation activity. This approach is consistent with several empirical studies found in the literature. Most notably, Lanjouw and Mody (1996) used pollution abatement expenditures as an indicator of the stringency of environmental regulations and found out that it is highly correlated with green patent activity in three countries (US, Japan and Germany). Although they successfully showed a correlation between expenditures and patents, the authors did not model nor explicitly test the relationship between abatement expenditures and environmental innovation in terms of econometric model. Jaffe and Palmer (1997) built a panel data set for US manufacturing industries to analyse how abatement expenditures affect patent activity in clean technologies, by looking at the total number of successful patent applications by industry. Nevertheless, they found little evidence that patent activity is related to abatement costs and they also include in their analysis all patents—whether environmentally related or not. Brunnermeier and Cohen (2003) employed several variable to proxy the role played by environmental regulations in fostering cleantech patent activity, such as pollution abatement costs and number of air and water pollution related inspections, but they did not specifically assess environmental taxes as a pivotal demand-policy instrument.

The following analysis mainly refers to the work by Costantini et al. (2015), who focused on the role played by different policy instruments on cleantech patent activity for a sample of OECD and non-OECD countries. Their analysis showed that demand-pull and technology-push instruments are both relevant in shaping the speed of technological change, thus revealing that a proper policy mix (that is capable to combine both types of policy support) is required to trigger a positive dynamic evolution of the technological trajectory in the cleantech sector. More specifically, they employed tax exemptions and the amount of R&D public funds as main regressors and the number of patents in specific technological fields as dependent variable within a standard OLS econometric model with lagged independent variable, delivering relevant and significant estimations of the coefficients. Therefore, as the approach adopted here makes use of taxes revenues as a proxy to estimate demand-policies influence on patent activity instead of tax exemptions, I expected to find a positive and significant relation with the response variable, though less strong than the case of tax exemptions which are directly linked to innovation incentives (Costantini et al., 2015).

3. Data, empirical model and econometric estimations

The empirical analysis has been carried out for 42 states out of a total of 50 in the United States. The reasons for excluding some States are mostly due to shortage of data for one or more variable, or because their patent profile within cleantech industries is nearly insignificant and would have led to misleading results.

I collected data on patents using OECD RegPat Database, which is a comprehensive dataset providing all patent applications to the European Patent Office (EPO) and to the US Patent and Trademark Office (USPTO) filed under the Patent Co-operation Treaty (PCT) and linked to more than 5,500 regions, using the inventors/applicants addresses (also covering regions from selected countries outside the OECD area). Biofuel patents fall under a number of patent classes, which have all been considered for the analysis and have been summarized in Table 1.

Table 1. Biofuel IPC Patent Classes

C10L005/00	C10L001/19	C11C001/02	C12N001/13
C10L005/40	C10L001/182	C11C001/19	C12N001/15
C10L005/48	C10L003/00	C12P003/10	C12N005/10
C10L009/00	C10B053/02	C12P007/06	C12N015/00
C10L001/00	C07C067/00	C12P007/14	C02F003/28
C10L001/02	C07C069/00	C12P005/02	C12M001/107
C10L001/14	C10G	C12N009/24	A01H

Source: OECD RegPat data

R&D expenditures data have been collected primarily using the National Science Foundation (NSF) surveys provided by the WebCASPAR Database [1], while taxes revenues data have been collected through the OECD Database on Instruments used for environmental policy[2].

A lag structure has been added to the model, as in Costantini et al. (2015), so that tax revenues and R&D data referred to the period 2000-2003, while the patent data to the period 2004-2007.

A linear regression has been run, using the total amount of patent in the biofuel sector in each State as dependent variable and the National green tax revenues data as main regressor, controlling also for the National R&D expenditure in order to neutralize the influence determined by the magnitude of public and private economic endeavors in terms of scientific activity. The model is then the following:

$$PATENTS_{i,04-07} = \beta_0 + \beta_1 TAXES_{i,00-03} + \beta_2 R\&D_{i,00-03} + \varepsilon_i \quad (1)$$

[1] Available online at https://ncsesdata.nsf.gov/webcaspar/

[2] Available online at http://www2.oecd.org/ecoinst/queries/Query_2.aspx?QryCtx=2

The results (see Table 2) are mostly consistent with the main hypotheses: green taxes have a positive and significant effect on patent activity in the biofuel sector. The coefficients are both significant, at least at 1.3% significance level, with t-values equal to 2.621 for the taxes variable and 4.501 for R&D. The overall R-squared is around 0.72, which is an average result for this kind of models, and the F-statistics is 50.82, with a strong significant p-value. Both regressors have a significant and positive, though slight, effect on the dependent variable. On average, an increase by one billion dollars of green tax revenues, keeping constant the amount of R&D expenditure in the State, would provoke an increase of around 1 patent in a given State. Moreover, R&D expenditures show, as expected, a significant impact on the response variable: an increase of one billion dollars of the R&D expenditures would determine an increase of around 2 patents in a given State.

Table 2. Econometric results

Residuals:				
Min	1Q	Median	3Q	Max
-16.8539	-3.6373	-0.1009	2.4651	23.0973
Coefficients:				
	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.520e+00	1.826e+00	-0.833	0.4100
TAXES	1.050e-06	4.007e-07	2.621	0.0124 *
R&D	1.970e-06	4.378e-07	4.501	5.95e-05 ***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Residual standard error: 8.619 on 39 degrees of freedom				
Multiple R-squared: 0.7227, Adjusted R-squared: 0.7085				
F-statistic: 50.82 on 2 and 39 DF, p-value: 1.373e-11				

Source: our estimation

4. Conclusion

The purpose of this work was to analyse the role of green taxes in fostering patent activity in the biofuel sector for a selection of States in the US. The econometric results are consistent with the main hypothesis that forecasted a significant and positive role of green taxes. Further analyses are due, including other variables to the model and, most notably, switching from a pure linear regression model to a OLS panel model, with a coherent lag structure of the independent variables.

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