SOCIAL AND PRIVATE OUTCOMES OF GREEN INNOVATION INCENTIVES IN EUROPEAN ADVANCING ECONOMIES

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Abstract

A question of particular importance in environmental policy is how to deliver eco-innovations with both private and social benefits. The question is even more important in emerging economies where pollution-intensive industries prevail and policies often favour growth over ecological concerns. This paper explores how four public incentives (regulation, taxes, subsidies and procurement of eco-innovations) and two private incentives (demand incentives and reputational concerns) contribute to the creation of private and social benefits from green (eco) innovations in emerging Central European economies. All six types of incentives have positive effects on the introduction of environmental innovations. Firms introduce innovations with benefits for end users only if they are accompanied by private benefits. The combination of regulation, procurement and financial incentives together with private incentives increase the likelihood of the introduction of environmental innovations with social benefits. This paper provides evidence-based recommendations for the management of environmental policies.

Keywords: eco-innovations; public and private incentives; social and private benefits; advancing economies

1. Introduction

The rising stringency of environmental policies and growing public concerns over pollution have recently increased the interest of academics and policy makers in innovations with environmental benefits (Barbieri et al., 2016; Pacheco et al., 2017). The desirability of eco-innovations arises from their double externality feature; they generate knowledge spillovers and pollution abatement externalities (Doran and Ryan, 2016). However, the costs of their development are often not met by end users with a greater willingness to pay. This appropriability problem puts society at risk of ending up with suboptimal levels of eco-innovations and excessive amount of negative environmental externalities (Johnstone et al., 2010).

The correction of eco-innovation market failure calls for an external intervention in the form of public incentives (e.g. regulation, taxes, subsidies or public procurement) and market incentives (e.g. consumer demand for eco-innovations or public opinion towards pollution) (Borghesi et al., 2015; Caravella and Crespi, 2020). These incentives can push firms towards the production of a socially desirable level of eco-innovations. However, if not aligned properly, they can also offset each other as noted in previous innovation policy literature (Stojcic et al., 2020; Greco et al., 2020).

The need for intervention in eco-innovation process is particularly strong in advancing (production-driven) economies where pollution-intensive technologies prevail (Horbach, 2016), policies favour developmental over environmental concerns (Lopes Santos et al., 2019) and structurally weak innovation systems do not provide sufficient impulse for organizations to innovate (Radosevic, 2017; Stojcic, 2020). Policy makers in such setting lack the knowledge about the actions needed to reduce environmental risks (Horbach, 2016). The provision of evidence-based policy recommendations in such setting may raise environmental awareness

and the eco-innovation efforts of organizations. However, the empirical evidence on eco-innovation in advancing economies is still scarce (Horbach, 2016; Lopes Santos et al., 2019).

Two literature gaps are particularly relevant for the context of this investigation. First, eco-innovation incentives can act independently or as a part of a policy mix (Rennings and Rammer, 2011). This calls for an investigation of the entire eco-innovation incentive system but so far, only a few studies have addressed the issue of policy mix in the eco-innovation context (Greco et al., 2020). In the context of advancing economies, only two studies have investigated individual effects of policy and non-policy based eco-innovation incentives (Li, 2014; Horbach, 2016).

Second, the existing studies assume that the introduction of eco-innovations creates by definition widening effects for society (De Marchi, 2012; De Marchi and Grandinetti, 2012; Borghesi et al., 2015; Souto and Rodriguez, 2015; Garcia Sanchez et al., 2020; Caravella and Crespi, 2020; Greco et al., 2020). The eco-innovations may generate benefits for innovating firms and society (De Marchi and Grandinetti, 2012; Galia et al., 2015; Doran and Ryan, 2016). but previous studies did not investigate whether some economic agents are more likely to receive benefits from eco-innovations than others. Only one study (Horbach, 2016) introduced a distinction between different categories of eco-innovation beneficiaries in the context of advancing economies and there is a need for further analysis of this issue.

Our paper aims to address both gaps by answering two research questions. First, what is the individual and combined effect of policy (public) and non-policy (private) external incentives on organizational decisions to introduce eco-innovations in advancing economies? Second, are the benefits of eco-innovations in advancing economies limited on innovating organizations or do they extend to the society as a whole? In answering these questions, we explore the role of four public incentives (environmental regulation, taxes, subsidies and public procurement of

eco-innovations) and two private incentives (market demand for eco-innovations and concerns over reputation) incentives for the introduction of eco-innovations. To the best of our knowledge this is the first such assessment of eco-innovation determinants and outcomes in advancing economies.

In the modelling of different types of eco-innovation benefits we distinguish among three categories defined as organizational, end users, and benefits for both firms and end users. The latter two categories are particularly relevant for our investigation. End users here refer to all economic agents outside of innovating organization, namely, consumers, other firms and government and can be thus treated as a proxy for society. The benefits for end users then, either alone or in combination with firm benefits, can be treated as widening effects from one group of economic agents (innovators) to other groups of economic agents (consumers, other firms and government) and can be referred to as benefits for the society.

The analysis is based on Community Innovation Survey (CIS) (2014) dataset, the most comprehensive source of information on the innovation behaviour of the firms in the European Union (EU). We focus on four Central and East European production-driven economies (Croatia, Hungary, Romania and Slovakia) characterised by weak innovation systems (Radosevic, 2017; Stojcic, 2020), pollution-intensive technologies (Horbach, 2016) and below average overall eco-innovation ranking in the context of the EU. The forthcoming Green Deal, the EU's initiative for the transformation of European economy according to the principles of sustainability, places these countries at the cross-roads between the developmental and environmental priorities. Learning what kind of incentives drives the eco-innovation behaviour of their firms and who the beneficiaries of eco-innovation are may help the formulation of an efficient environmental policy package in these countries and, more importantly, all advancing countries confronted with a trade-off between developmental and environmental priorities.

Methodologically, the study builds on the treatment analysis framework (Rosenbaum and Rubin, 1983) with public and private eco-innovation incentives being considered as treatments. Such approach overcomes the potential endogeneity issue from the self-selection of firms in one of the treated categories or picking-the-winner strategy by incentive providers (Radicic et al., 2016; Stojcic et al., 2020). The existing eco-innovation literature has not paid particular attention to this issue with only two studies employing such empirical strategy in the analysis of eco-innovation determinants and outcomes (Ghisetti, 2017; Greco et al., 2020), which calls for further investigation.

The results of the investigation show that, unless induced by demand, firms will introduce innovations with benefits for society only if such innovations accompany some benefits for themselves. The strongest effects on the introduction of eco-innovations come from private incentives and regulation. In all but two cases policy mix has a stronger effect than individual incentives. We take this as an evidence of multifaceted nature of eco-innovation market failure and argue that reaching of socially desirable level of eco-innovations requires a multi-dimensional approach that would aim at the introduction of eco-innovations by firms and their adoption by consumers.

The paper is structured as follows. The next section sets the conceptual framework of the analysis. Section three presents the empirical strategy of the paper. Section four brings the results of the investigation. The discussion of findings is in section five. Finally, conclusions, policy implications, directions for further research and limitations of the paper are given in section six.

2. Conceptual framework

2.1. The concept of eco-innovations

Eco-innovation is commonly defined as an innovation capable of reducing pollution, improving efficiency of use and sharing of resources and reducing environmental risks (Barbieri et al.,

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2016; Mavi and Mavi, 2021). Apart from these socially desirable effects, environmental innovations have the potential to change the economic structure by giving birth to new technological paradigms and trajectories (Pacheco et al., 2017). At a micro level, eco-innovations can boost organizational productivity through better resource and cost efficiency, the application of novel technologies and the development of technological capabilities. In the sophisticated market segments environmental concerns serve as a signal of higher quality and as means of differentiation (Doran and Ryan, 2012).

The determinants of eco-innovation can be looked for in the internal and external dimensions of organizations (Borghesi et al., 2015). The evidence from several (mostly Western European) countries suggests that eco-innovators have a high organizational absorptive capacity (Stanovcic et al., 2015; Cainelli et al., 2015), larger size and better performance (De Marchi and Grandinetti, 2012), invest in intramural R&D (Doran and Ryan, 2016) and in R&D training (Galia et al., 2015). Studies from China (Cai and Zhou, 2014), Germany (Horbach et al., 2012) and the United Kingdom (Kesidou and Demirel, 2012) show that corporate social responsibility (CSR) strategies and environmental management systems (EMAS) help firms in the early stages of the innovation process. Garcia-Sanchez et al. (2020) show that the presence of institutional owners in the organizational ownership structure has a positive effect on the implementation of proactive environmental strategies and commitment towards the organizational sustainability.

Common barriers to eco-innovation include the lack of relevant knowledge, high switching costs from the established technologies and the incompatibility with the existing socio-cultural norms and individual needs (Cecere et al., 2014). A high degree of novelty, uncertainty and variety makes eco-innovations highly dependent on the synergies between internal and external knowledge (De Marchi, 2012; Galia et al., 2015; Costantini et al. 2017a) with customers and rivals (Doran and Ryan, 2016), the providers of generic research such as universities and

research institutions (De Marchi and Grandinetti, 2013; Horbach et al., 2013; Triguero et al., 2013) and suppliers (Dai et al., 2015).

2.2. External incentives to eco-innovations

A common challenge of all innovation processes is the appropriability of the returns on innovation (Johnstone et al., 2010). Innovations generate technological spillovers that prevent the appropriation of full gains by inventors. In the case of eco-innovations this problem is even more pronounced with their double-externality nature (Horbach et al., 2012; Doran and Ryan, 2016). A considerable portion of eco-innovation benefits stretches to society through improvements in the environmental quality, while the costs of innovation process fall on eco-innovators (Borghesi et al., 2015; Caravella and Crespi, 2020). It follows that firms generally have little/no incentive to engage in eco-innovation activities unless they are induced (or forced) to do so by some kind of external incentive (Borghesi et al., 2015; Doran and Ryan, 2016).

The external incentives for eco-innovation can be explained with the Hicksian model of induced innovation (Newell et al., 1999). According to this model, changes in the relative prices of production inputs can motivate the search for innovations and can lead to the reconfiguration of the production process towards a predominant use of a relatively inexpensive input. Following the same logic, it can be argued that the external eco-innovation incentives, whether public or private, motivate the search of firms for ways of achieving higher process efficiency and greater product value (Porter and van der Linde, 1995). Such actions yield an additional benefit by preventing socially undesirable underinvestment in innovations and an excessive amount of negative environmental externalities (Johnstone et al., 2010). In the eco-innovation literature this model is known as the Porter Hypothesis (PH) (Porter and van der Linde, 1995). It suggests that governments can achieve a win-win situation, in which society benefits from a higher level of environmental protection and firms improve their ability to compete.

The empirical evidence on PH is mixed (Ramanathan et al., 2017). Among different policy instruments, PH considers regulation as a particularly important instrument that provides informative and normative content of eco-innovation process (Porter and van der Linde, 1995). It seems that regulation facilitates the introduction of eco-innovations if it works through push and pull incentives (Doran and Ryan, 2012) and that its effects vary across pollution categories (Horbach et al., 2012), sectors (Rennings and Rammer, 2011), recipients of environmental benefits (Doran and Ryan, 2016) and the innovation intensity of firms (Borghesi et al., 2015). Its stringency matters for the intensity of investment in eco-innovations while the decision to innovate seems to be more driven by customers and societal requirements (Doran and Ryan, 2012; Kesidou and Demirel, 2012).

Besides regulation, governments can reduce the opportunity costs of environmental innovation through pollution taxes and penalties, tax exemptions on environment friendly technologies (Rennings and Rammer, 2011) or through public subsidies and the procurement of eco-innovations (Ghisetti, 2017). The positive effects of environmental taxes were found in technology intensive industries (Johnstone et al., 2010; Costantini et al., 2015), while the evidence on public subsidies is mostly not significant (Horbach et al., 2013; Triguero et al, 2013). Ghisetti (2017) also notes that risks associated with uncertain demand and early development of eco-innovation can be reduced through public procurement.

The correction of eco-innovation market failures sometimes goes beyond the scope of a single policy instrument or even one policy area (Rennings and Rammer, 2011). This is the case with eco-innovations as general innovation policies target common market failures of the innovation process, such as knowledge spillovers while environmental policies are designed to address environmental externalities (Greco et al., 2020). The general innovation literature has investigated the individual and combined effects of innovation policies (Stojcic et al., 2020). However, the issue of policy mix has been touched upon by only a few studies in the eco-

innovation context. Veugelers (2012) and Costantini et al. (2017b) have reported positive policy mix effects on the outcomes of the eco-innovation process. Greco et al. (2020) reported additionality effects from the combination of general and eco-innovation policy instruments over individual general innovation policies. However, they failed to find an evidence of the policy mix supremacy over individual eco-innovation policy measures in the short and long run.

The general innovation literature recognised a long time ago that impulses for innovation can come outside of public policies through consumer demand or public opinion (von Hippel, 1986). In the eco-innovation context, the demand pull incentives were recognised as the source of information about emerging market trends, the willingness to pay for certain technologies and the preferences for specific types of products (Borghesi et al., 2015). The same study notes that public opinion pressure threatens the reputation of an organization and can also act as a trigger for the engagement in eco-innovation activities. Similar to public policy instruments, these incentives can act upon firms alone or in combination with other public and private incentives.

2.3. Eco-innovation incentives in environmentally advancing countries

We now move to developing the framework and hypotheses of our investigation. The previously reviewed body of knowledge originates from advanced countries. These countries are known for their functioning and stringent policy frameworks and a range of private incentives for eco-innovation (Horbach, 2016; Lopes Santos et al., 2019). Only two studies reviewed for the purpose of this investigation have focused on advancing economies (Li, 2014; Horbach, 2016). Moreover, none of the reviewed studies have investigated the combined effects of public and private eco-innovation incentives in the context of either advanced or advancing

economies. To fill these gaps, we extend the previously presented theoretical and empirical arguments and argue why the failure to address both issues might not be trivial.

The understanding of the drivers and outcomes of eco-innovations in advancing countries is important for several reasons. In a functional innovation environment, public and private eco-innovation incentives could lead to a win-win situation for firms and policy makers. This takes place through the building of innovation competences and capabilities of indigenous firms and the building of a higher level of environmental protection for society. However, advancing economies such as the economies of the CEE countries are different from their advanced counterparts. They are embedded in pollution intensive technologies (Horbach, 2016), their innovation systems do not provide sufficient impulse to innovation (Radosevic, 2017; Stojcic, 2020) and their policy makers are more concerned with the developmental than environmental objectives (Lopes Santos et al., 2019). Whether the eco-innovation incentives exist in such setting and what effects they produce is a question that requires further investigation. This enables us to formulate our first hypothesis:

H1: Public and private incentives facilitate the creation of innovations with environmental benefits in the context of advancing CEE economies.

As noted previously, rather than being self-driven, eco-innovations are policy-led (Doran and Ryan, 2016). It follows that firms will not engage in eco-innovations if they cannot benefit from such activities. The external incentives should, in such setting, motivate firms not to introduce any type of eco-innovations but, more importantly, those eco-innovations with the widening effects to society (Johnstone et al., 2010). In the context of advancing economies (including CEE countries), the eco-innovation literature explored the effects of individual policy instruments such as regulation or subsidies (Horbach, 2016) but there are no investigations of the public and private incentive effects on the choice of enterprises between eco-innovations

with individual benefits and benefits for end users or society. This leads to our second hypothesis:

H2: Public and private incentives facilitate the creation of innovations with benefits for end users (society) more than eco-innovations with benefits for firms in the context of advancing CEE economies

H2a: Public and private incentives facilitate the creation of innovations with environmental benefits for end users (society) more than eco-innovations with benefits for firms in the context of advancing CEE economies

H2b: Public and private incentives facilitate the creation of innovations with environmental benefits for both firms and end users (society) more than eco-innovations with benefits for firms in the context of advancing CEE economies

The environmental awareness of advancing economies is lower than the awareness of their counterparts in advanced world and their policy makers lack relevant knowledge (Horbach, 2016). This creates a potential problem in the design and implementation of eco-innovation policies. As recognised in the general innovation literature, misaligned and uncoordinated innovation policies have the potential to offset each other (Stojcic et al., 2020). In the eco-innovation context, Greco et al. (2020) have recently shown that the policy mix of general and eco-innovation policies yields stronger effects than general innovation policies on their own. However, no differences have been found between policy mix and individual eco-innovation policies. The eco-innovation market failure is multi-faceted and reflects itself in incomplete appropriability, financial barriers, uncertain demand and informational failures (Caravella and Crespi, 2020). This suggests that the combination of incentives from one or more policy areas could be more efficient in correcting market failure than individual measures.

The existing literature has not explored how a policy mix, made up of different public and private eco-innovation incentives, influences the choice of firms between the eco-innovations with benefits for themselves and with widening effects. This leads to our third and final hypothesis:

H3: Combined public and private eco-innovation incentives generate stronger effects on the creation of innovations with environmental benefits for end users (society) than individual eco-innovation incentives in the context of advancing CEE economies.

3. Empirical strategy

3.1. Sample characteristics

As noted previously, the central objective of our investigation is to assess the effect of individual and combined public and private eco-innovation incentives on the introduction of eco-innovations with benefits for firms and for society. Databases with information on environmental practices of firms are extremely rare and only a few of them enable the assessment of determinants and outcomes of eco-innovation (Mazzanti et al., 2016; Ghisetti, 2017). Our analysis builds on the data from the Community Innovation Survey (CIS) database. CIS is a bi-annual database on the innovation activities of the firms in the EU member states and its candidate countries. It has been used in previous general innovation studies (Stojcic et al., 2020) and eco-innovation studies (Greco et al., 2020). It is compiled by Eurostat and the Statistical Offices of the EU member states. To maintain a sufficient responsiveness and quality, the CIS dataset is anonymised and can be accessed only through the Eurostat's safe room or its secure servers.

The access to data for respective countries is subject to approval of each EU member state. In practice, this may result in complete or partial refusal of access to data for individual countries. For the purpose of this investigation, an access to the most recent available version of CIS dataset has been granted covering 21.052 firms during the 2012-2014 period in four new Central

and Eastern European EU member states, Croatia, Hungary, Romania and the Slovak Republic. These four countries can be regarded as production driven economies. As we have already noted, the literature describes them as dominated with pollution-intensive technologies (Horbach, 2016), having weak innovation systems (Radosevic, 2017; Stojcic, 2020) and below average overall eco-innovation ranking in the context of the EU. Figure 1 provides the share of firms that introduced environmental innovations for themselves, end users or both themselves and end users. Here one can see that all four analysed countries are characterised with less than 50% of firms involved in environmental innovation.

Figure 1: Firms involved in environmental innovation
(% of total no. of firms)
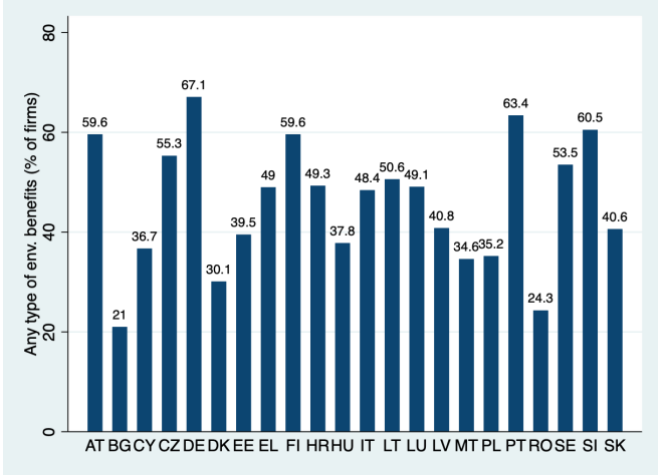
Source: Eurostat CIS 2014 (data on Spain not available)

In all EU member states, a convincing majority of eco-innovations have resulted in benefits for the organization while less than 8% of all benefits could be attributed to the end users (Figure 2). The differences are particularly striking in the countries that are the subject matter of this analysis. In Romania, only 1% of firms have declared that their environmental innovations have resulted in benefits for end users, while in Croatia, Hungary and Slovakia these numbers are beyond 5%.

Figure 2: % of firms involved in environmental innovation by type of beneficiaries
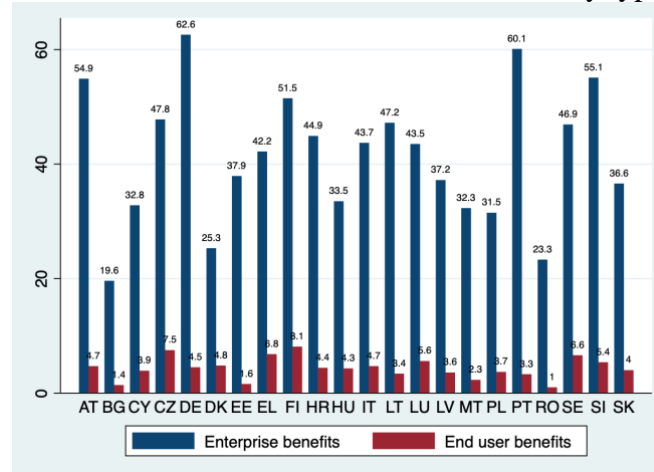
Source: Eurostat CIS 2014 (data on Spain not available)

Previous rounds of CIS were criticised for the construction of selected questions that may pave the way for potential endogeneity. The commonly cited sources of such endogeneity refer to the focus on regulation over other eco-innovation incentives and the limitation of some questions on innovating firms (Mazzanti et al., 2016). Such issues do not pose a problem in our dataset for at least three reasons. First, our version of the dataset provides information on a wide range of public and private eco-innovation incentives. Second, the potential endogeneity was recognised in the context of the relationship between eco-innovation incentives and firm performance (Mazzanti et al., 2016). Our study is focused on the introduction of eco-innovations. Finally, our empirical strategy takes into account the potential selection bias that may arise from some questions being answered only by innovating firms.

3.2. Model specification

The outcome variables in our model are able to take into account different categories of the beneficiaries from eco-innovations. CIS dataset asks survey participants whether the introduction of eco-innovations has created benefits for the innovating organization and for end users (consumers, other firms and government). The eco-innovation benefits for organizations include i) reduced material or water use per unit of output, ii) reduced energy use or CO_2 footprint, iii) reduced air, water, noise or soil pollution, iv) reduced use of polluting or

hazardous materials, v) replacement of fossil energy with renewable energy sources and vi) recycling of waste, water and materials for own use or for sale. The innovations with benefits for end users (consumers, firms and government) or society refer to environmental innovations with the following types of benefits: i) reduced energy use or CO_2 footprint, ii) reduced air, water or noise pollution, iii) easier recycling of products after use and iv) extended durability of products.

From these answers, we have constructed three dichotomous variables taking the value of one if firms have introduced eco-innovations with benefits for themselves, for end users and for both themselves and end-users. Conceptually, our approach builds on previous investigations of the eco-innovation incentives and outcomes (Horbach et al., 2012; Triguero et al., 2013; Horbach, 2016). What distinguishes our approach from these studies is a wider scope of eco-innovation incentives including private ones and our focus on advancing economies.

Among external eco-innovation incentives we focus on four public policy instruments and two private/market incentives. Public policy instruments include i) regulation, ii) environmental taxes, charges and fees, iii) grants and subsidies and iv) public procurement of eco-innovations. Among private/market incentives our model includes v) market demand and vi) reputational concerns of an organization. These variables are considered as treatments in our model. The treatment in our analysis is defined in the following way. A firm is considered as treated if over analysed period it considered as moderately or highly important for the introduction of eco-innovation one of our six previously defined incentives. To this end, we follow the approach laid out in Horbach et al. (2012).

The choice of variables in the modelling of the treatment assignment process has been driven by predictions from other studies and the availability of data in the CIS dataset. Following several eco-innovation studies (Kesidou and Demirel, 2012; Cainelli et al., 2015;

Stanovcic et al., 2015; Ghisetti, 2017; van Leeuwen and Mohnen, 2017) we control for firm size on the basis of number of employees, for knowledge accumulation through ongoing and abandoned innovation activities and through the involvement in R&D activities over the analysed period. We also control for knowledge sharing among the firms that are part of an enterprise group and for collaborative innovation with entities such as suppliers, customers, rivals or universities.

The model controls for firms that have a functional environmental management system (EMAS) (Horbach et al., 2012; Dai et al., 2015). Stricter environmental regulations abroad can mean that in order to export some organizational resources have to be devoted to environmental innovation (Stanovcic et al., 2015). For this reason, the model includes a dummy variable for exporting firms. The quality of human capital, proxy for the absorptive capacity of an organization, is controlled with categorical variable for firms that employ at least 10% of staff with tertiary education (Cainelli et al., 2015). Finally, the model includes sectoral and country dummy variables to control for universal cross-sectional shocks affecting all firms (Rennings and Rexhauser, 2011; Triguero et al., 2013). Tables A1, A2 and A5 in the Appendix provide a detailed definition and summary statistics of the variables.

3.3. Econometric strategy

A common assumption in the existing literature is that public and private incentives determine the creation of eco-innovations in conjunction with other internal and external firm characteristics (De Marchi and Grandinetti, 2013; Dorian and Ryan, 2016; Horbach, 2016; Caravella and Crespi, 2020). In reality, the assignment of a particular public or private policy incentive to individual firms may be non-randomised as firms may self-select on certain observable characteristics or treatment providers (e.g. public agencies) may adopt "picking the winner" strategy to maximise the effects of incentive (Radicic et al., 2016; Ghisetti, 2017;

Greco et al., 2020). A solution to this problem is to estimate the effect of external eco-innovation incentives as a treatment assignment through a quasi-experimental approach and non-parametric matching method. Such approach has been widely known in the general innovation literature (Almus and Czarnitzki, 2003; Stojcic et al., 2020) but, to the best of our knowledge, only two eco-innovation studies have recognised the issue and used the treatment technique (Ghisetti, 2017; Greco et al., 2020).

To address the potential endogeneity problem, we have adopted the treatment analysis framework (Rosenbaum and Rubin, 1983). Typically, researchers wishing to assess the impact of specific incentives or policies (treatment) can observe the outcome for the recipients of a treatment, while the potential counterfactual outcome cannot be observed. The way around this problem is the establishment of a control group of firms that are as similar as possible to the treated firm but do not receive the treatment. Methods capable of performing such task are known in the literature as matching methods (Imbens and Wooldridge, 2009; Guerzoni and Raitteri, 2015). They are based on the conditional independence assumption (CIA). This means that the selection into treatment is as good as random subject to a set of observable covariates.

The most commonly used matching estimator is the nearest neighbour matching (NNM) procedure (Greco et al., 2020). This estimates in the first step the propensity score of the probability of the treatment receipt. In the second step, the distance in the propensity scores between two groups is minimised by selecting one control observation for each firm that is treated. Finally, the model calculates the average treatment effects on the treated (ATT) as a difference in the potential outcome means between two groups. Our empirical strategy employs NNM first to assess the effect of individual public and private external incentives on the creation of eco-innovations with benefits for organizations, end users and both groups. We then limit our sample on firms that have introduced any kind of eco-innovations. This allows us to explore whether external incentives motivate firms to introduce eco-innovations with benefits

for organizations, society or both and whether the combinations of public-public and public-private incentives are more efficient in motivating creation of eco-innovations with benefits for society than the individual policy measures.

An issue of particular relevance in treatment analyses is the one of the hidden bias. It may arise from unobservable factors which affect both the receipt of treatment and the analysed outcome. The presence of such hidden bias would make outcomes dependent on the treatment status. The way around this problem is modelling the treatment assignment process as a function of all factors that could drive the assignment of firms into each treatment category. The appropriate design of the model in this way can make the treatment assignment process as good as random, conditional on the included variables (Cattaneo, 2010).

Such modelling strategy is appropriate for two reasons. First, the questions on the relevance of particular innovation incentives are answered only by firms that have introduced environmental innovation. The prevalent strategy in previous literature was to focus only on innovating firms or to perform analyses in the tradition of CDM models where focus is on the handling of the selection bias between innovating and non-innovating firms. In our approach, we address the potential selection bias arising from both construction of our dataset and from the potential correlation with other covariates to estimate the effects of incentives for eco-innovation on the creation of environmental benefits for organizations and for end users.

4. Results of investigation

Our empirical analysis begins with the assessment of determinants behind the perception of environmental innovation incentives. Dependent variables from probit estimation in Table 1 take the value of 1 if any of our eco-innovation incentives are recognised as moderately or highly important for firms. These results enable us to calculate the propensity scores needed for subsequent matching procedure. Firms with previous experience, investment in R&D and

collaborative innovation activities are more likely to assign medium or high importance to all eco-innovation incentives (Table 1). Being part of an enterprise group increases the importance of reputational concerns while exporters view regulation, taxes, demand and reputation as moderately or highly important facilitator of eco-innovation. We also observe in all but one case, the positive effect of organizational environment management system (EMAS).

Table 1. Probit results (dep.variable: importance of the incentives for eco-innovation)

Variables/ Treatment	Regulation	Taxes	Subsidies	Procurement	Demand	Reputation
Group	0.06 (0.128)	0.02 (0.038)	-0.01 (0.045)	0.01 (0.042)	0.01 (0.039)	0.06* (0.035)
Exporter	0.08** (0.023)	0.09** (0.037)	-0.01 (0.043)	-0.03 (0.040)	0.09** (0.038)	0.08** (0.034)
Innovation experience	0.48*** (0.049)	0.49*** (0.051)	0.35*** (0.057)	0.28*** (0.056)	0.41*** (0.050)	0.54*** (0.048)
R&D investment	0.54*** (0.047)	0.40*** (0.049)	0.51*** (0.055)	0.46*** (0.054)	0.60*** (0.049)	0.56*** (0.046)
Human capital	-0.01 (0.032)	-0.01 (0.034)	-0.01 (0.039)	0.01 (0.037)	0.06* (0.049)	0.02 (0.032)
Cooperation on innovation	0.75*** (0.047)	0.64*** (0.049)	0.51*** (0.055)	0.60*** (0.053)	0.67*** (0.048)	0.74*** (0.046)
Emas	0.60 (0.034)	0.50*** (0.035)	0.44*** (0.041)	0.48*** (0.039)	0.51*** (0.036)	0.55*** (0.033)
Small firm	0.17*** (0.037)	0.20*** (0.038)	0.13*** (0.045)	0.12*** (0.042)	0.14*** (0.039)	0.13*** (0.036)
Medium sized firm	0.34*** (0.047)	0.33*** (0.049)	0.12** (0.058)	0.18*** (0.054)	0.22*** (0.050)	0.26*** (0.047)
Country and sector fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	21.052	21.052	21.052	21.052	21.052	21.052

Source: Own calculations. ***,** and * denote statistical significance at 1%, 5% and 10% levels, respectively. Standard errors in parentheses

The validity of the hypotheses was assessed through the nearest neighbour matching procedure with an exact matching on the country and sector of the firm[1]. The average treatment effects on the treated (ATT) in Table 2 reveal that all external incentives have a positive and statistically significant effect on the introduction of eco-innovations with benefits for firms and of those with widening effects to end users (or society). This confirms H1. The regulation, demand and

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[1] Relevant model diagnostics are presented in Online appendix. Table A3 shows that standardised differences between coefficients are close to zero and weighted variance ratios are close to one. Results from Rosenbaum bounds analyses (Tables A4a-A4c) do not reveal sensitivity of results to underestimation or overestimation due to hidden bias at levels above 100%. The overlap of the propensity scores across treatment levels was examined in Figures A1-A3. These figures do not reveal any evidence of overlap assumption violation. Together, all these diagnostics provide support to our model.

reputational concerns have strongest effect on the decision to introduce eco-innovation[2]. We find statistically significant differences in magnitude of incentive coefficients in all cases except between eco-innovations with benefits for firms and those with benefits for end users.

Table 2. Treatment effects of individual public and market incentives (ATT effects)

Incentives	Eco innovations with benefits for		
	Firms	End users	Firms and end users
Regulation	0.89*** (0.014)	0.83*** (0.031)	0.84*** (0.018)
Taxes	0.85*** (0.017)	0.78*** (0.043)	0.77*** (0.016)
Subsidies	0.79*** (0.026)	0.74*** (0.052)	0.71*** (0.021)
Procurement	0.83*** (0.023)	0.80*** (0.048)	0.73*** (0.019)
Demand	0.82*** (0.020)	0.84*** (0.034)	0.80*** (0.016)
Reputation	0.87*** (0.015)	0.83*** (0.031)	0.87*** (0.013)

Source: Own calculations. ***,** and * denote statistical significance at 1%, 5% and 10% levels respectively. Standard errors in parentheses. Baseline category: Firms that do not consider eco-innovation incentive as moderately or highly important (dep.variable: Probability of introduction of environmental innovation with benefits for organization, end users or both)

To assess whether the external incentives increase the chances for the introduction of eco-innovations with widening effects (those with benefits for end users and for firms and end users) over eco-innovations with benefits for firms only, we reduce our sample to firms that introduced any type of environmental innovation. Table 3 shows that the chances for the introduction of eco-innovations with benefits for end users over those with benefits for firms (baseline category) are lower among the firms that consider regulation and taxes as moderately or highly important and higher among the firms that assign a greater importance to market demand. Positive and statistically significant effects are found from all incentives on the introduction of eco-innovations with benefits for firms and end users. The strongest effects come from demand and reputational concerns[3]. These findings confirm our H2b while H2a is confirmed only partially in the case of the market demand incentive.

Table 3. Treatment effects on individual types of benefits (ATT effects)

Incentives	Eco-innovations with benefits for	
	End users	Firms and end users
Regulation	-0.08* (0.039)	0.18*** (0.033)
Taxes	-0.09*** (0.032)	0.10*** (0.027)

[2] Statistical significance of differences between coefficients on individual eco-innovation incentives was determined with Wald tests. Results are available upon request.
[3] Statistical significance of differences between coefficients on individual eco-innovation incentives was determined with the Wald tests. Results are available upon request.

Subsidies	-0.05 (0.038)	0.08*** (0.028)
Procurement	-0.02 (0.040)	0.12*** (0.028)
Demand	0.09*** (0.032)	0.18*** (0.028)
Reputation	-0.01 (0.035)	0.22*** (0.032)

Source: Own calculations. ***,** and * denote statistical significance at 1%, 5% and 10% levels respectively. Standard errors in parentheses. Baseline category: Firms that introduced environmental innovation with benefits for firms only. (dep.variable: Probability of introduction of environmental innovation with benefits for end users or end users and organization)

We have further assessed whether a combination of incentives (policy mix) is more efficient than individual incentives in motivating the firms to introduce the eco-innovations with benefits for society over those with benefits limited to themselves. The baseline category here are the firms that introduce eco-innovation with benefits for themselves and consider one of the eco-innovation incentives as moderately or highly important. The treated firms are those that consider all incentives included in the policy mix as moderately or highly important. Six types of incentive combinations were explored: i) regulation and taxes, ii) regulation and subsidies, iii) regulation and procurement, iv) subsidies and procurement, v) regulation, subsidies and procurement or financial incentives, vi) all public incentives, vii) demand and concern over reputation and viii) joint effect of public and private incentives.

The combination of private incentives (Table 4) is the only policy mix that increases the chances for eco-innovations with benefits for end users. In the case of eco-innovations with benefits for firms and end users, all policy mixes except the one of regulation and taxes increase the propensity towards eco-innovations with benefits for firms and end users.

Table 4. Treatment effects of combined public and/or private incentives on introduction of environmental innovations with particular type of benefit (ATT effects)

| | Eco-innovations with benefits for | |
Incentives	End users	Firms and end users
Regulation and taxes	-0.07 (0.050)	0.02 (0.031)
Subsidies and procurement	-0.00 (0.050)	0.07* (0.037)
Regulation and subsidies	-0.01 (0.041)	0.05* (0.062)
Regulation and procurement	0.01 (0.044)	0.11*** (0.032)
Regulation and financial incentives	-0.00 (0.051)	0.09*** (0.031)
All public incentives	-0.07 (0.050)	0.08*** (0.032)
Demand and reputation (private incentives)	0.07* (0.038)	0.14*** (0.033)
Public and private incentives	-0.03 (0.053)	0.09*** (0.033)

Source: Own calculations. ***,** and * denote statistical significance at 1%, 5% and 10% levels respectively. Standard errors in parentheses. Baseline category: Firms that introduced environmental innovation with benefits

for firm only and consider individual incentives as moderately or highly important. (dep.variable: Probability of introduction of environmental innovation with benefits for end users or end users and organization)

Finally, we assessed the effect of policy mix against each individual incentive. For each policy mix, two samples were constructed. In each sample, the firms that consider one incentive included in the policy mix as moderately or highly important and introducing eco-innovations with benefits for firms are taken as the control group, while firms considering the policy mix as moderately or highly important are the treated category. Other individual incentives are excluded from the analysis.

Table 5. Treatment effects of combined public and/or private incentives vs individual policy measures (ATT effects) – eco-innovations with benefits for end users only

Combined incentives	Individual incentive 1	Coef. (st.error)	Individual incentive 2	Coef. (st.error)
Regulation and taxes	vs. regulation	-0.09 (0.052)	vs. taxes	0.16*** (0.017)
Subsidies and procurement	vs. subsidies	0.03 (0.072)	vs. procurement	0.04 (0.069)
Regulation and subsidies	vs. regulation	-0.02 (0.042)	vs. subsidies	0.02 (0.077)
Regulation and procurement	vs. regulation	-0.01 (0.045)	vs. procurement	-0.01 (0.081)
Regulation and financial incentives	vs. regulation	-0.02 (0.694)	vs. financial incentives	0.05 (0.068)
All public incentives	vs. regulation	0.05 (0.056)	vs. subsidies	-0.03 (0.052)
	vs. taxes	-0.09 (0.076)	vs. procurement	-0.04 (0.054)
Demand and reputation (private incentives)	vs. demand	-0.10 (0.085)	vs. reputation	0.12*** (0.038)
Public and private incentives	vs. public	0.10 (0.063)	vs. private	-0.17 (0.079)

Source: Own calculations. ***,** and * denote statistical significance at 1%, 5% and 10% levels respectively. Standard errors in parentheses. Baseline category: Firms that introduced environmental innovation with benefits for organization only and consider as moderately or highly important one of incentives included in policy mix. (dep.variable: Probability of introduction of environmental innovation with benefits for end users or end users and organization)

In the case of eco-innovations with benefits for end users mix of private incentives (demand and reputational concerns) delivers stronger effects than reputational concerns alone (Table 5). Similar finding holds for combination of regulation and taxes over taxes alone.

Table 6. Treatment effects of combined public and/or private incentives vs individual policy measures (ATT effects) – eco-innovations with benefits for firms and end users

Combined incentives	Individual incentive 1	Coef. (st.error)	Individual incentive 2	Coef. (st.error)
Regulation and taxes	vs. regulation	0.02 (0.034)	vs. taxes	0.003 (0.067)
Subsidies and procurement	vs. subsidies	0.21*** (0.061)	vs. procurement	0.02 (0.043)
Regulation and subsidies	vs. regulation	0.06* (0.030)	vs. subsidies	0.15** (0.066)
Regulation and procurement	vs. regulation	0.10*** (0.032)	vs. procurement	0.13* (0.074)
Regulation and financial incentives	vs. regulation	0.09*** (0.032)	vs. financial incentives	0.18** (0.074)
All public incentives	vs. regulation	0.14** (0.060)	vs. subsidies	0.10*** (0.034)
	vs. taxes	0.10** (0.042)	vs. procurement	0.12*** (0.038)

Demand and reputation (private incentives)	vs. demand	0.19*** (0.067)	vs. reputation	0.17*** (0.034)
Public and private incentives	vs. public	0.07 (0.069)	vs. private	-0.01 (0.038)

Source: Own calculations. ***,** and * denote statistical significance at 1%, 5% and 10% levels respectively. Standard errors in parentheses. Baseline category: Firms that introduced environmental innovation with benefits for organization only and consider one of the incentives included in the policy mix as moderately or highly important. (dep.variable: Probability of introduction of environmental innovation with benefits for end users or end users and organization)

In all but two cases we find stronger effects from policy mix than from individual incentives on the propensity of firms towards eco-innovations with benefits for firms and end users (Table 6). Together, these findings suggest that our H3 can be confirmed partially across both specifications.

5. Discussion

In this paper we have argued that two issues stand out as particularly important in the eco-innovation context, namely eco-innovation incentives and eco-innovation beneficiaries. Neither of these issues has been addressed by the existing literature in a comprehensive manner. Studies have explored the effects of individual eco-innovation incentives (De Marchi, 2012; Souto and Rodriguez, 2015; Borghesi et al., 2015; Galia et al., 2015; Doran and Ryan, 2016). Only a few studies have included a wider range of eco-innovation incentives (Li, 2014; Horbach, 2016; Caravella and Crespi, 2020) or have addressed the issue of policy mix (Greco et al., 2020). This is so despite the fact that the decision of firms to engage in eco-innovation can be influenced by several public and private incentives. (Rennings and Rammer, 2011; Doran and Ryan, 2016).

Literature has also recognised that eco-innovations generate benefits for innovating firms and society (De Marchi and Grandinetti, 2012; Galia et al., 2015; Doran and Ryan, 2016). However, whether some economic agents are more likely to receive benefits from eco-innovations than others has not been a matter of previous investigation. In this context, it is important to understand what factors lead to eco-innovations whose benefits are not only reserved for innovators but generate widening effects to other economic agents in society (other firms, consumers and government). These issues are particularly relevant in advancing countries

where pollution-intensive technologies dominate (Horbach, 2016), innovation systems are weak (Radosevic, 2017) and policy is more focused on developmental than environmental goals (Lopes Santos et al., 2019).

Our investigation is one of rare studies to explore the eco-innovation behaviour of the firms in advancing economies and one of the first attempts to assess the combined and individual effects of a wide range of public and private incentives on the decision of firms to introduce eco-innovations with benefits for themselves and eco-innovations with socially desirable widening environmental effects.

As our results show, all analysed incentives increase the propensity of firms towards the introduction of eco-innovations. However, unless induced by demand, firms will introduce eco-innovations with benefits for society only if benefits for themselves come along. This is consistent with the traditional eco-innovation view (Porter and van der Linde, 1995), i.e. that for society to achieve a win-win outcome both firms and society must receive some kind of benefits from eco-innovation activities. The strongest positive effects to the introduction of eco-innovations with benefits for firms and society come from reputational concerns, demand and regulation. In all but two cases we have found that policy mix induces stronger effects than individual policy incentives. This supports the view that the decision of firms to engage in eco-innovation is influenced by several external incentives from the same or different policy areas (Rennings and Rammer, 2011). Also, it speaks in favour of argument that eco-innovation policy should cover incentives for both creation and adoption of eco-innovations (Greco et al., 2020).

Our findings should also be placed in the context of their geographical setting, i.e. that of the production-driven economies. As argued by previous literature (Horbach, 2016; Lopes Santos et al., 2019), firms and policy makers in such setting care more about developmental than environmental objectives. The strongest effects of demand and reputation along with an almost

complete lack of incentive effects on eco-innovations with benefits for end users suggest that firms in such settings view eco-innovation primarily as a market trend and engage in such practices if they recognise benefits for themselves.

The results of investigation are not directly comparable with other studies as none of the previous studies explored whether some economic agents are more likely to receive benefits from eco-innovations than others. We have identified only a few studies that have explored the effects of the combined eco-innovation incentives at firm level (Veugelers, 2012; Greco et al., 2020) and studies that have explored the effects of eco-innovation incentives in production-driven economies (Li, 2014; Horbach et al., 2016). Finally, only two previous studies (Ghisetti, 2017; Greco et al., 2020) have employed econometric strategy similar to ours.

Taking these constraints into account, our findings on the selected individual eco-innovation incentives closely match the findings from other studies. In production-driven economies, Horbach (2016) finds positive effects of regulation, subsidies and demand on the introduction of eco-innovations with benefits for firms and for end users while Li (2014) finds positive effects of regulation and foreign demand on the implementation of environmental innovation practices in organizations. However, these two studies are not concerned with the combined effects of eco-innovation incentives or the differences in benefits from eco-innovation. To some extent, our analysis of the combined and individual eco-innovation incentives can be compared to the findings from Veugelers (2012) and Greco et al. (2020). However, these two studies are concerned with complementarities between general innovation and eco-innovation policies while the focus of our investigation is on eco-innovation incentives.

Overall, our findings bear three important messages. First, in the context of our production-driven economies, the public and private incentives instigate the creation of eco-innovations but the widening effects seem to be present only when firms recognise the gains for themselves.

Second, the combination of eco-innovation incentives produces greater additionalities than the implementation of individual measures. One should also add that the strongest incentives for the introduction of eco-innovations with benefits for society are found from demand and reputational concerns, followed by regulation and procurement. This clearly signals the importance of the pull or demand side channel for instigation of societal benefits from environmental innovations and the need for a combination of the established eco-innovation instruments such as regulation with novel innovation policies, e.g. public procurement. Finally, strongest effects of demand and reputational concerns also suggest that correction of eco-innovation market failure should involve measures aimed at both introduction of eco-innovations and their adoption by consumers.

6. Conclusion

The growing concerns over environmental issues across the developed and the developing economies have raised the interest of policy makers, academics and business community in the development of novel, environment friendly solutions that can be applied in business and everyday life. Sustainable development and socially responsible organizational behaviour may increase the efficiency and productivity of not only firms but also their sectors and the entire economies over medium to long run. Yet, concerned with their short-term prospects of declining performance and competitiveness, many economic agents demonstrate resistance towards the new environmental trends. Public intervention is needed to remedy the market failure in the suboptimal creation of environmental innovations and to increase the benefits not only for organizations but for the society as a whole. Motivated by this need, we have conducted a study that has theoretical, policy and practical implications.

6.1. Theoretical implications

The case for the intervention in eco-innovation process is built around the argument that innovations with environmental benefits provide two types of favourable outcomes, i.e. direct benefits for firms and indirect benefits for other economic agents in society such as consumers, other firms and government. While the issue has been recognised for some time (Doran and Ryan, 2016; Galia et al., 2015) the question whether some economic agents are more likely to receive benefits from eco-innovations than others has not been a matter of previous investigation. Our study fills this gap and shows that firms introduce eco-innovations with widening effects to society only if such effects are accompanied by prospects for their own benefits.

Another theoretical implication of our study comes from its assessment of combined vs. individual eco-innovation incentives. Only a few firm level studies have attempted to explore the effect of the policy mix on eco-innovation outcomes (Veugelers, 2012; Greco et al., 2020). However, none of these studies have explored the differences between individual and combined eco-innovation incentives. Our study supports the theoretical argument that the decision of firms to engage in eco-innovation is influenced by several external incentives from the same or different policy areas (Rennings and Rammer, 2011). As the first study of such kind, our investigation shows which incentive combinations provide stronger effects on the introduction of eco-innovations than individual incentives.

6.2. Practical implications

Our study provides novel findings on the impact of individual and combined eco-innovation incentives on the introduction of different types of eco-innovations in the production-driven economies. As our findings show, in such settings the combination of policy incentives in almost all cases generates stronger effects on the introduction of innovations with social

benefits than individual incentives. This means that there exists some degree of complementarity between the analysed incentives and that a multi-dimensional approach to the correction of eco-innovation market failure may instigate additionality effects. It is also evident that private eco-innovation incentives (demand and reputation) have a stronger effect on the introduction of eco-innovations than public incentives. This could be caused by a well-known weaknesses of innovation systems (Radosevic, 2017) and an absence of the policy focus that would specifically target eco-innovations (Lopes-Santos et al., 2019) in production-driven economies.

Another explanation is that the dominance of the pollution-intensive technologies (Horbach, 2016) makes environmental issues less important in advancing economies such as our four CEE economies. This could also be due to the fact that public incentives are designed in a way to promote the creation rather than the adoption of eco-innovations (Greco et al., 2020). The analysed countries are among the least environmentally advanced European Union member states with low levels of environmental awareness. Firms may not respond to public incentives for the introduction of eco-innovations with benefits for end users because the demand for such products does not exist. Our dataset did not allow a deeper investigation of the reasons for the absence of the relationship between external incentives and the introduction of eco-innovations with benefits for end users and this remains an issue for future investigations.

6.3. Policy implications

Policy makers and academic community are still not at the stage where a clear policy framework towards eco-innovations is in place. Debates are ongoing about the appropriateness of individual and combined institutional, market-based, supply-push and demand-pull policies. One still has to find the way how to bring the different eco-innovation policy instruments together. Above all this, there is evidence that market mechanism (through demand and public

opinion) provides incentives in the field of environmental innovation, which are of an equal or even larger magnitude than the public incentives. The challenge for policy makers, then, goes beyond the search for an optimal combination of public policy instruments. It also involves the exploration of pathways to combine public and private incentives in order to achieve the well-being of organizations and of the society as a whole.

Our policy implications are as follows. From our results, firms seem more responsive to private than public incentives. This opens another indirect policy channel and suggests that, in the setting of advancing countries with loose environmental policies, the policy package should not be limited to conventional public policy instruments. By raising public awareness about environmental issues and consumer responsibility towards the environment, policy makers can foster the adoption of eco-innovations and generate a powerful incentive for firms to engage in eco-innovation activities.

When it comes to the creation of eco-innovations with benefits for society, the statistical significance of all individual and almost all combined incentives in the model with benefits for firms and society confirms the view that eco-innovation market failure is a multifaceted problem. The strongest effects of market demand, reputation, regulation and procurement imply that the sources of market failure lie in uncertain demand, incomplete appropriability, financial barriers and informational failures (Caravella and Crespi, 2020). Our evidence shows that individual policy measures are in nearly all cases inferior to policy mix. This calls for a multi-dimensional approach towards the correction of the eco-innovation market failure that will encompass measures in above mentioned areas. Our evidence shows that the combinations of regulation with procurement and with financial incentives and the combinations of market demand and reputation are among the most significant cross-instrumental effects on the introduction of eco-innovations with benefits for firms and society (at 1% level of significance).

6.4. Limitations and directions for future research

Lastly, one should reflect on the limitations of our research and provide some directions for future research. Our analysis is based on a rich dataset of four previously unexplored production-driven economies. However, an extension of the investigation to other production-driven economies would strengthen arguments of our study and add to generalisability of our findings. One way to increase the public support for the transition towards environment-friendly technologies and business practices is to reveal all the benefits for the economy from such move. As noted previously, such benefits are visible only in the medium to long run. The research estimating these effects is still relatively scarce, mostly due to the absence of longitudinal firm and industry datasets on environmental innovation and environmental business practices in general (Greco et al., 2020). The provision of efficient inputs to policy makers and increasing public support for environmental innovations will depend on the ability of the research community to provide evidence-based information on all benefits coming from the activities in this area and to communicate these benefits in a clear and transparent manner.

It remains on the researchers of tomorrow to address these challenges.

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