Regional environmental and energy policies: are they effective for the sustainable transition of listed companies?

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ABSTRACT

We test the effectiveness of environmental and energy policies, complying with legal requirements and followed voluntarily, on endeavours towards green and energy transitions. With this aim, a sample of Italian listed firms in 2008-2019 is investigated. The empirical framework is developed by means of a propensity score matching analysis with multiple treatments, implemented in both a panel data and cross-sectional contexts. Our results show that regional interventions operate as a push/pull mechanism in driving companies to be more environmentally friendly. This is important for identification of policy-driven changes which make some regions more successful than others in sustainability transition.

Keywords: Regional policies; General policies for reducing air emissions; Renewable energy policies; Energy efficiency policies; Sustainability transition; Firm environmental performance.

1. Introduction

Policymakers and public opinion almost unanimously agree that climate change is the most serious problem the world is facing. Tackling environment-related challenges by 2030 will determine the sustainable future of the planet (United Nations, 2015).

Climate change is a global phenomenon, but its effects differ from place to place. It thus requires a strong policy response on a local, as well as a wider, scale (OECD, 2021). The shift towards sustainability requires fundamental changes in lifestyles, technologies, and business models (Markard et al., 2012; Lindberg et al., 2019). Many factors make regional and local authorities central to achieving climate goals. First, subnational governments are closer to citizens and abler to read local vulnerabilities. They are also essential for mobilizing finance, activating production chains, and promoting innovation (Carfora et al., 2017; Arbolino et al., 2022). Moreover, energy transition plays a key role in this process. Regional governments also have crucial competencies in terms of climate and energy policies, promoting the development of renewable energy sources as well as a more efficient use of existing ones.

The growing attention towards environmental problems should lead the industrial mix and enterprise fabric of cities and regions to focus more on the environmental impacts of their business and take active roles in environmental management (Walker & Wan, 2012; Horbach & Rammer, 2018). The re-alignment between territorial priorities is thus necessary for real greening of the economy. But '*understanding the role of policy processes in influencing the rate and direction of sustainability transitions remains a fundamental challenge*' (Edmondson et al., 2018, p.1).

Regional government is a key player in the implementation of strategies for new technologies, standards, and regulations. It also supports institutions at national and global levels. At the same time, large incumbent firms show the capabilities, long-term vision, and resources necessary to successfully grow more sustainably than smaller companies with fewer resources (Boschma et al., 2017; Horbach & Rammer, 2018).

Listed companies are thus encouraged to use a variety of instruments for green and energy-efficient behaviours. *Voluntary* internal policies have been particularly important since the 1990s. However, to the best of our knowledge, so far only Patchell and Hayter (2021) have explicitly analysed the role of large incumbent firms in creating a voluntary market for commercial and industrial electricity purchases in the USA. It was found that many smaller companies in fact followed their lead.

It is worth noting that voluntary policies can coexist with and complement regional interventions, which in turn may be a sort of '*role model*' for firms (Beise & Rennings, 2005; Horbach & Rammer, 2018). However, there is currently no systematic evidence on this interaction (Boschma, 2017).

This paper aims to fill this gap. Our research lies at the crossroads between regional, environmental, management and finance studies. The connection between these different research fields allows us to investigate how listed firms react to local environmental policies and market challenges brought by sustainable transition. The paper takes a novel perspective to examine the effectiveness of environmental and energy policies on a sample of Italian listed enterprises in the period 2008-2019.

From an environmental point of view, Italy is of particular interest because it is the fourth-largest emitter of greenhouse gases in the European Union (IEA, 2016). It shows strong and persistent territorial differences (Ghisetti & Quatraro, 2013). These characteristics affect company approaches to sustainability issues (Gazzola et al., 2020). So, they make it appropriate to conduct the empirical analysis at regional level.

We propose several innovations regarding existing literature. Firstly, our analysis confirms the small amount of previous evidence that firms located in provinces in advanced regions are more likely to promote institutional change and new activities than firms in peripheral regions (Boschma, 2017). This is consistent with the structure of our sample; most of our listed firms are located in the Po Valley, in the North of Italy. This is the most advanced industrial area of the country, but also one of the most heavily polluted in the world.

Secondly, this is the first empirical analysis of the sustainable transition of listed firms in Italy. This is of great importance because the industrial sector in Italy is largely structured as a network of non-listed small and medium enterprises (SMEs). Their transition to sustainability is closely influenced by the strategies of listed firms. Listed companies are geographically close to SMEs and can in fact trigger learning and imitation processes and leader-follower relationships.

Thirdly, unlike previous literature (Santoalha & Boschma, 2021), we examine a wide range of interventions, not necessarily related to one specific type of green activity. We look at general policies for reducing air emissions, renewable energy policies and energy efficiency policies. This approach makes it possible to analyse sustainable transition of firms from two complementary points of view: *green transition*, i.e., lowering air emissions and making production processes cleaner, and *energy transition,* i.e., lowering the use of fossil fuels and encouraging efficient energy use. 'Regional discourse' is particularly relevant in this context because of the risk firms face of being locked into a dominant and 'brown' regional technological and specialization regime (Antonioli et al., 2016).

Lastly, there are many studies on the effects of regional capabilities and spatial spillovers on firm profitability (Castelnovo et al., 2020; Barbero et al., 2021) and the effects of local characteristics on regional macro-performance (Camagni & Capello, 2013; Perucca, 2014). But to date there is little literature on how regional environmental and energy interventions impact on firm environmental performance (Jenniches at al., 2019).

The paper is structured as follows. Section 2 analyses the role of regional authorities in fighting climate change and presents the main research hypotheses. Section 3 presents the sample and describes the data and methodology. Section 4 presents the main empirical results. Section 5 discusses policy implications. Section 6 concludes.

2. Regional authorities and climate change

Environmental and sustainable energy policies require collaboration and coordination at all levels of governance. Supranational, national, regional, and local authorities are all involved in the transition to sustainability. Multi-level governance helps to create synergies between state and non-state actors. It should ensure effective and equitable climate governance (Jänicke, 2017). The literature has paid increasing attention to the spatial rescaling of environmental and energy policies. This process is in fact influenced by many factors: complexity, capacity, environmental awareness, market barriers and geographical specificity.

Environmental and energy problems are extremely complex. They require radical and systematic solutions across multiple dimensions. National government cannot in general afford this level of complexity. Only local authorities, in compliance with state guidelines, have the capacity to implement appropriate policies (Sørensen & Torfing, 2016; Mendez et al., 2021). Despite their limited resources for managing these growing responsibilities (Barca, 2009), subnational authorities play a key role in the administration, planning and management of climate-related spending, investments, and funding (Spilanis et al., 2016; Carfora et al., 2017; OECD, 2021).

When regional government is aware of environmental problems, it is more likely to promote interventions for pro-active green behaviours (Dai et al., 2015). This can have important repercussions on enterprises and their stakeholders (De Rynck & McAleavey, 2001; Mendez et al., 2021). Green activities can in fact be very difficult in regions hosting dirty industries (Acemoglu et al., 2016; Santoalha & Boschma, 2021). This implies that there is greater willingness to act for environmental preservation in 'healthy' regions, and less where there is a greater incidence of polluting sectors (Cicatiello et al., 2020).

Regional regulations and policies can thus provide a 'role model' and encourage firms in the transition towards sustainability (Dangelico & Pujari, 2010; Horbach & Rammer, 2018). Public policies are also determinant in sustainability transition because of the presence of market barriers, i.e., high initial costs impacting on firm development and adoption of environmental strategies (Lindberg et al., 2019; Caragliu, 2021).

Local differences in economic activity, and industrial and technological specialisation, are also based on geography. Firms often agglomerate in specific areas to exploit local natural resources, socio-political and technological aspects, infrastructure, formal and informal institutions, regional and urban schemes, and culture-based imaginaries (Hansen & Coenen, 2015; Boschma et al., 2017). This implies that the development of green activities is generally unequal, involving only certain regions and cities (Antonioli et al., 2016). A high number of firms involved in green transition in an area will boost economies of scale and lower the cost of adopting environmentally friendly technologies (Rigby, 2015).

Place specificity affects a region's ability to design successful environmental policies (Coenen & Truffer, 2012; Hansen & Coenen, 2015). It impacts on the transition towards a zero-carbon energy era (Michalena & Angeon, 2009; Morton et al, 2018; Zeng et al., 2019). Coenen et al. (2021) distinguish studies on energy transition into three groups: (i) *in,* (ii) *of*, and (iii) *by* regions. Studies in group (i) look at place-specific factors, such as regional industrial capabilities, institutions, resource endowments, policy portfolio and market configurations; in group (ii) at regional sector structures, such as employment and innovation systems, and in group (iii) at regions as 'agents of change'. Local factors can in fact enhance the effectiveness of renewable energies and energy efficiency policies especially in terms of firm choices (Horbach & Rammer, 2018; Caragliu, 2021).

Although regional authorities are in general strongly committed to climate goals, previous literature has not investigated the specific role of regional policies in influencing the green and energy transitions of firms. We therefore test the following hypotheses:

H_1: Regional environmental policies boost the green transition of firms.

H_2: Regional renewable energy policies boost the energy transition of firms.

H_3: Regional energy efficiency policies boost the energy transition of firms.

Regional government is not however the only key player on the local scale. Regional authorities coexist with other local actors, including firms and citizens, which are embedded in local networks and particularly relevant for sustainability transition (Hansen & Cohen, 2015). Geographical proximity favours coordination and local inter-organizational networks between actors who are characterized by big cognitive and cultural differences. The emergence of new industrial pathways in regions can reflect the alignment of different resources, like knowledge, markets, investments, and legitimacy (Rohe & Chlebna, 2021; Tsouri et al., 2021).

Regions diversify on the basis of firms present on the ground. Regional strategic leeway may depend on policies formulated at firm level (Boschma, 2017; Boschma et al., 2017). This means that a single public policy instrument will often not act as a silver bullet and will not be sufficient in itself to stimulate green and energy transition. It is the context, coordination, timing and scale of different policies acting together that will create sustainable challenges for companies and competitive gains (Rogge & Reichardt, 2016; Scordato et al., 2018).

Moreover, Horbach and Rammer (2018) highlight that the effectiveness of policy mix in renewable energy depends on several firm-specific features. These include the fact that bigger firms have fewer financial constraints, which favors their shift from fossil energy to renewables. It also fosters the re-organization of the whole production process to being more environmentally friendly. Firm size is also shown to be important for energy efficiency investments (Costa-Campi et al., 2015). Patchell and Hayter (2021) specifically analyse the role of large companies in energy transitions in the USA. They show that incumbent firms take an active role in the sustainability process in specific regions. We believe that this finding is particularly relevant to Italy, where listed companies were the first to adopt voluntary environmental policies in the 1990s (Lamboglia et al., 2018).

Despite the importance of policy mixing, no studies have so far assessed the effectiveness of regional and firm-specific policies in *jointly* influencing green and energy transition processes. We therefore test the following hypotheses:

H_4: Regional and firm-specific environmental policies boost the green transition of firms jointly.

H_5: Regional and firm-specific renewable energy policies boost the energy transition of firms jointly.

H_6: Regional and firm-specific energy efficiency policies boost the energy transition of firms jointly.

3. Sample, data and methodology

3.1. The sample

The sample consists of 63 Italian listed firms, selected from the 228 Italian companies listed on the Italian Stock Exchange (MTA, Mercato Telematico Azionario) at the end of 2019. Only 63 of these published environmental disclosure reports in the period 2008-2019.[1]

Figures 1 and 2 about here

Figure 1 maps the distribution of the sample across the 110 provinces of Italy. Listed companies have their headquarters in provinces belonging to ten regions, mainly in Northern and Central Italy.[2] These are the most industrialized and entrepreneurially developed geographic areas of the country, where there is also greater diversification of industrial activities (ISTAT, 2022). This is consistent with the structure of our sample, as the 63 firms belong to six heterogeneous industries, not necessarily involved in the transition process (Figure 2).

The focus on listed companies is interesting from different points of view. Firstly, listed firms are particularly involved in addressing climate change and environmental issues (Gutsche & Ziegler, 2019), as financial markets are currently showing higher levels of environmental concern (Eurosif, 2018; US SIF, 2020). This implies that identifying environmental performance indicators, monitoring, and communicating trends to stakeholders has in fact become crucial for listed companies (Eccles et al., 2017). Secondly, SMEs in Italy are numerous. Listed company strategic decisions can impact on SMEs through geographical proximity, imitation processes, and leader-follower relationships.

Larger firms also play a key role in terms of sustainability transition because knowledge spillovers within regions boost the development of pro-environmental strategies. Local industrial specialization often stimulates the introduction of selective regional policies, which in turn underpin technological and industrial specialization (Hansen & Coenen, 2015).

3.2. Firm environmental performance indicators

Different measures of firm environmental performance are extracted from Refinitiv® Eikon-Datastream. This is one of the world's most comprehensive financial time series databases. It collects historical series data on '*bond indices, bonds, commodities, convertibles, credit default swaps, derivatives, economics, energy, equities, equity indices, Environmental, Social and Governance (ESG) estimates, exchange rates, fixed income, funds, fundamentals, interest rates, and investment trusts*'.

[1] The years 2005-2007 are not included because of the very low number of items.
[2] Specifically, Lombardy exhibits the highest concentration of firms (39.68%), followed by Emilia Romagna, Lazio, Piedmont, and Veneto (15.87%, 14.29%, 7.94% and 6.35%, respectively). The remaining companies (15.87%) are in Tuscany, Liguria, Friuli Venezia Giulia, Sardinia, and Marche.

Specifically, we consider the ESG Section, which is a rich source of information on environmental, social and governance scores.[3] The variables employed are: CO_2 equivalent emissions (hereafter CO_2 emissions), the Emission Category Score, and the Environmental Pillar Score.

CO_2 emissions are generated and emitted by each firm. They are measured in tons and represent the negative externality of the industrial process on the environment. They are computed by considering direct and indirect greenhouse gas emissions classified into Scope 1 and 2 by IPCC (2006).

The Emission Category Score measures firm efforts for reducing emissions in production and operational processes. The Environmental Pillar Score measures the firm's environmental rating and, more generally, its global environmental performance. The two indexes represent firm attempts to make production processes environmentally friendly and establish an efficient environmental management system. They range from 0 to 100. They are calculated using voluntary information published in the company environmental reports. Although the use of quantitative data might be preferable (Iraldo et al. 2009), the use of self-reporting qualitative data is not uncommon (Barla, 2007; Bang et al., 2019).

3.3. Policy variables

Our empirical framework is characterized by the presence of three distinct categories of environmental and sustainable energy policies, considered independently and classified as follows: (*i*) general policies for reducing air emissions, (*ii*) renewable energy measures, and (*iii*) energy efficiency measures.

Regarding regional policies, data are retrieved from the database `*Air quality improvement measures*'. It is compiled by the Italian Institute for Environmental Protection and Research (ISPRA) for the years 2008-2011. This is a repository of the information provided annually by Regions and Autonomous Provinces since 2005 to comply with national and European legislation on air quality improvement plans. We consider interventions classified as '*Industrial plant emissions control*', '*Renewable energy sources*', and '*Energy efficiency sources*'. These correspond to policy classifications (*i*)-(*iii*) and capture regional interventions for reducing air emissions and promoting the use of renewable energy and energy efficiency measures.

Regarding firm-specific voluntary policies, data are obtained from Refinitiv® Eikon-Datastream, Section ESG Scores. We consider the variables '*Policy Emissions*', '*Resource Reduction Policy*' and '*Policy Energy Efficiency*', which are voluntary actions corresponding to three types of policy (*i*)-(*iii*). More precisely, the first series captures firm decisions to reduce air emissions. It answers the question '*Does the company have a policy to improve emission reduction?*'. The second and third variables capture firm implementation of renewable energy initiatives and energy efficiency measures. They answer the questions '*Does the company have a policy to reduce the use of natural resources or to reduce the environmental impact of its supply chain?*' and '*Does the company have a policy to improve its energy efficiency?*'. These are qualitative variables and take values of '*True*' or '*False*'.

[3] For further information: https://www.refinitiv.com/content/dam/marketing/en_us/documents/quick-reference-guides/esg-data-in-eikon-march-2021.pdf.

3.4. Methodology

For each policy category (*i*)-(*iii*), three mutually exclusive groups of policy are defined as follows:

1. P_0: no regional and no firm policies are applied;
2. P_R: the firm does not implement any internal policy but is located in a region implementing policies;
3. $P_{R,F}$: the firm is located in a region applying policies and also implements internal policies.

Three distinct treatment indicators, related to the three categories of policy (*i*)-(*iii*), are built. They take values equal to 0, 1 and 2 if P_0, P_R and $P_{R,F}$ respectively hold. For each type of intervention (*i*)-(*iii*), our empirical analysis aims to compare the effects of these three mutually exclusive strategies P_0, P_R and $P_{R,F}$ on firm environmental performance. We thus distinguish two treatments, corresponding to the two levels of application of each policy category (regional only and regional and internal jointly). A more generalized version of propensity score matching which isolates the effects of multiple treatments on the variable of interest is used (Lechner, 2001).

Average treatment effects on the population (*ATTs*) are then estimated in the following pairwise comparisons:

- P_R/P_0: regional policies *versus* no regional and no firm policies;
- $P_{R,F}/P_R$: regional policies implemented together with voluntary policies *versus* regional policies;
- $P_{R,F}/P_0$: regional policies implemented together with voluntary policies *versus* no regional and no firm policies.

The pairwise comparison of the effects of treatment *m* and *l* can thus be defined as:

$$ATT_{m,l} = E(Y^m - Y^l|P = m) = E(Y^m|P = m) - E(Y^l|P = m) \quad (1)$$

where $ATT_{m,l}$ denotes the expected average effect of treatment *m* relative to treatment *l* for each firm randomly selected from the population receiving treatment *m*, *Y* is firm environmental performance, and *P* represents the mutually exclusive policies described above.

The term $E(Y^m|P = m)$ is not observable. So, under the conditional independence assumption, Equation (1) is rewritten as follows:

$$ATT_{m,l} = E(Y^m|P = m) - E_X\{E(Y^l\,|X, P = l|P = m)\} \quad (2)$$

where *Y* is independent of the treatment and is conditional on a set of observable covariates (*X*). They capture the main features of the province where the firm is located and some firm characteristics, as described in Subsection 3.5. Equation (2) shows that the outcome of firms receiving treatment *m* can be proxied by the outcome of others undergoing treatment *l*, as they have similar characteristics. The only difference between these two groups of matched firms is the implementation (or not) of certain types of regional and internal policies.

Matching is obtained by using the probability of each firm of implementing and/or being subject to certain policies, i.e., the specific treatment *m,* conditional on the values taken by a vector of covariates (*X*):

$$p^m(X) = Prob(P = m|X) \quad (3)$$

The probability introduced by Equation (3) is the propensity score. In our framework, it is estimated using a multinomial logistic model. By jointly considering Equations (2) and (3), we obtain Equation (4), which is the core of our estimation strategy:

$$ATT_{m,l} = E(Y^m|P = m)E_{p^m(X),p^l(X)}E(Y^l|P^m(X), P^l(X), P = l)|P = m) \quad (4)$$

Equation (4) is estimated by using three distinct dummies corresponding to status 1 and 2 of the treatment indicator. A detailed description is given in Appendix A.

Finally, in each of the three pairwise comparisons, the quality of the matching procedure between treated and untreated firms is tested with what is called the balancing hypothesis.

3.5. Explanatory variables

Two distinct sets of explanatory variables are included in Equation (3). One set captures heterogeneities on a province scale and the other firm-specific features.

A set of covariates is introduced to represent the main socio-economic characteristics of the province where each firm has its headquarters. In fact, place specificity and local related capabilities are extremely important for a successful sustainability transition (Boschma et al., 2017; Coenen et al., 2021). These are: GDP at current market prices (in Euro per inhabitant) and the number of persons employed in active enterprises in industry, construction and services (except insurance activities of holding companies). These are both measured by NUTS 3 regions and retrieved from Eurostat (regional statistics).

Specifically, GDP captures the stage of development of each province, which differs considerably across the twenty regions of Italy. Higher levels of development are mainly found together with greater awareness of environmental issues and greater willingness to act in an environmentally friendly way (Lo & Chow, 2015). The number of persons employed in active enterprises in industry, construction and services is used to proxy the level of employment in each province.[4] This variable captures the economic motives underlying local authority decisions to stimulate the development of cleaner industries and economic competitiveness (Hansen & Coenen, 2015; Lehr et al., 2016).

The second set of variables covers firm-specific characteristics: liquidity, profitability and firm size. Liquidity is measured by inventories: the lower the inventory, the higher company liquidity. Profitability is proxied using Return on Equity (ROE). The index is calculated as the ratio between net income and total equity: the higher ROE, the higher company profitability. Firm size is proxied by total assets: the higher total assets, the bigger the size. Data on firm-specific characteristics are retrieved from Refinitiv® Eikon-Datastream and are measured in euros.

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[4] Data on employment and/or unemployment rates by NUTS 3 regions have been available only since 2018 (data source: ISTAT).

We expect that more profitable companies with higher liquidity will perform better environmentally because they have more economic and financial resources to invest in sustainability initiatives. A positive relationship between firm size and environmental performance is also assumed. In fact, since 2017 companies with more than 500 employees have been under a mandatory reporting constraint, which should encourage them to improve environmental performance.[5]

4. Empirical results

4.1. Preliminary evidence

4.1.1. Stylized facts

For each policy category (*i*)-(*iii*), we classify companies into three mutually exclusive groups, according to the type of policy applied: regional policy adopters, regional and internal policy adopters, and no regional and no firm policy adopters. Stylized facts are reported in Table 1.

Table 1 about here

With regard to Case (*i*), firms adopting regional policy exhibit the highest per capita GDP of the sample and a high level of employment. These companies are characterized by low emission levels, but also by a weak environmental performance in terms of Emission Category Score and Environmental Pillar Score. Moreover, regional policy adopters show low liquidity, low profitability, and small size.

Firms implementing both regional and internal policy are big, profitable, and liquid. Their headquarters are also located in developed regions showing the highest levels of employment. They also show the best environmental performance in terms of firm commitment to reducing emissions and environmental rating. They are however the most polluting companies of the sample.

Firms implementing no regional and no firm policies are located in the less developed regions, are characterized by quite low employment and emission levels, but also by a weak environmental performance in terms of Emission Category Score and Environmental Pillar Score. These companies are of small size and show the highest liquidity but also the lowest profitability.

Lastly, renewable energy and energy efficiency policies (Cases *ii* and *iii*) yield similar results to general policies for reducing air emissions (Case *i*).

4.1.2. Estimates of the propensity scores

In a panel data framework,[6] a multinomial logistic model for each policy category is then estimated (Table 2). For Cases *i-iii*, the dependent variable identifies the status of each

[5] European Directive 2014/95/EU, the 'Non-Financial Reporting Directive', has been in force in Italy since January 25, 2017. It requires public-interest companies, including banks, insurance companies and listed firms with more than 500 employees to disclose information on how they manage social and environmental challenges. Italian law specifies that the non-financial statement must report at least the following information in the environmental section: greenhouse gas emissions and polluting emissions into the atmosphere, the use of energy and water resources and the impact on the environment and on health and safety. Risk factors and other significant environmental and health risk factors must also be reported.

[6] The panel data framework is characterized by 63 firms in the time period 2008-2019.

firm for the mutually exclusive strategies P_0, P_R and P_{RF}. Given that the dependent variable is obtained by merging both regional and firm policies (see Appendix A), explanatory variables capture local features as well as firm specific aspects. Firm fixed effects are also included.

Table 2 about here

Overall, our results show that macroeconomic factors are especially important for the implementation of energy policies.[7] The specific impact of firm characteristics varies according to the type of policy. In fact, liquidity conditions matter especially in the case of energy measures. This is the case of regional and internal policy adopters: the higher firm liquidity, the greater the adoption of these measures. The opposite holds in the case of general policies applied on a regional scale. Profitability boosts the implementation of renewable energy policies in both levels of application (regional only and regional and internal jointly). This also holds when energy efficiency measures are applied only on a regional scale.

On the other hand, firm size seems to discourage the adoption of renewable and energy efficiency policies at a regional level, while the greater the firm size, the greater the adoption of energy efficiency measures both at regional and internal level. These mixed results probably reflect the fact that Italian companies with more than 500 employees have only been under a mandatory environmental reporting constraint since 2017. This constraint will probably emerge as an incentive for them to improve company environmental performance in the next few years.

For each policy category (*i*)-(*iii*), propensity scores are obtained from results shown in Table 2. These propensity scores are estimated by means of the nearest neighbor algorithm with caliper width of 0.20 standard deviations as a matching technique.[8] They are then used to compute the average treatment effects (Equation 4). The estimated treatment effects are reported as a percentage of the untreated outcome means. This allows us to measure the effectiveness of the different combinations of policies in terms of firm environmental performance. These results are discussed in the following subsections.

For each policy category and for each environmental performance indicator, we test the quality of the matching between treated firms (i.e., firms subject to only regional policy or subject to regional policies and applying voluntary interventions at the same time) and control firms (i.e., either firms not applying any kind of policy or only subject to regional policies) by means of the conventional balancing hypothesis.[9] Results indicate that observations with the same propensity score have the same distribution as observable characteristics (Table 3). The presence of possible spatial spillover between policies

[7] These multinomial logistic regressions were also computed by using per capita GDP and unemployment rate by NUTS 2 regions. Results are mainly in line with those reported in Table 2. They are available from the authors on request.

[8] The number of neighbors used to calculate the matched outcome is 5. Various caliper widths of standard deviations (i.e., between 0.20 and 0.70 with increment 0.05) were tested. When possible, a caliper width equal to 0.20 is preferred, as indicated by Wang et al. (2013) and Santika et al. (2017).

[9] The following diagnostic tests, computed before and after matching, were run: (a) the Pseudo R^2 associated with the estimations of the propensity scores; (b) The likelihood-ratio test of the joint insignificance of all the regressors (LR χ^2) and the corresponding p-values ($p > \chi^2$); (c) the values of the Mean and Median Bias and the associated reduction in bias (in percentage points); (d) the Rubin B and R tests (Rubin, 2001).

adopted is also tested using three global spatial autocorrelation statistics: Moran's *I*, Geary's *c*, and Getis and Ord's *G* tests. Results reported in Table 4 show that sample firms are not spatially correlated, so the estimates are unbiased and consistent.[10]

Tables 3 and 4 about here

Lastly, robustness analyses were made to test the sensitivity of the main results. First, Equation (4) was re-estimated in a panel data context where the matching framework characterized by a number of neighbours equal to 1 and without the use of a caliper. In this case, propensity scores were computed by means of multinomial probit regressions. Secondly, the analysis was repeated in a cross-sectional framework. The year 2011 was taken as reference year to measure the effectiveness of the three types of policy on the proxies of firm environmental performance measured in 2019.[11] Results are reported in Appendix B.

4.2 The effects of the three distinct types of environmental and energy policy on firm environmental performance

4.2.1. CO_2 emissions

Sustainable environmental and energy policies play a key role in *reducing* the level of CO_2 emissions generated by firms. Equation (4) represents the differences in terms of CO_2 emissions between the treated companies and the matched ones. The three distinct policy categories are expected to have a *negative* average effect on emissions.

Table 5 about here

Comparing firms located in regions implementing policies with firms located in regions that do not apply any kind of policy (P_R/P_0), shows that environmental and energy policies are effective (Table 5). They boost the green and energy transitions of firms. The estimated coefficients are in fact negative, as expected, and highly statistically significant. These findings thus support H_1, H_2 and H_3 in relation to reduction of CO_2 emissions.

When P_{RF}/P_R and P_{RF}/P_0 are instead considered, general policies significantly raise CO_2 emissions rather than reducing them. So, H_4 relating to the reduction of CO_2 emissions is not supported. A similar finding is made by Kim and Lyon (2011) in their study of the impacts of firms' strategic disclosure of greenhouse gas reductions in the USA. In an analogous way, robustness checks cast doubt on the effectiveness of renewable energy and energy efficiency policies (Table B7 in Appendix B). So, H_5 and H_6 are not supported in relation to the reduction of CO_2 emissions. This is in line with Baiardi (2020), when analyzing the impacts of energy efficiency policy on CO_2 emissions in Italian provinces.

4.2.2. Emission Category Score and Environmental Pillar Score

Following the procedure described in the previous subsection, we consider the impact of sustainable environmental and energy policies on the Emission Category Score and the Environmental Pillar Score. In this case, the three distinct policy categories are expected

[10] If spatial effects are present in the treatment assignment, they violate the Stable Unit Treatment Value Assumption for empirical treatment effect analysis.

[11] In this case, propensity scores are estimated by means of a multinomial logistic model. The number of neighbors used to calculate the matched outcome is 5 and a caliper width of 0.20 standard deviations is used in most cases.

to have a *positive* average effect on the two indicators. The main results are reported in Tables 6 and 7.

Tables 6 and 7 about here

When policies are implemented only on a regional scale (P_R/P_0), the estimated effect on firm environmental endeavor and global environmental performance is negative (Tables 6 and 7). This counterintuitive result is robust independently of the type of policy category and of the indicator analyzed (Tables B3, B4, B8 and B9 in Appendix B). These findings suggest the rejection of H_1, H_2 and H_3 when firm environmental performance is measured in terms of efforts to reduce emissions in production and operational processes and global environmental performance.

On the other hand, the co-presence of regional and internal policies, i.e., the pairwise comparisons P_{RF}/P_R and P_{RF}/P_0, have a significant positive impact on both the Emission Category Score and the Environmental Pillar Score. So, with regard to these two indicators, H_4, H_5 and H_6 are accepted. The average improvement is particularly significant (about 93% and 75%) when general policies for reducing air emissions are considered (Tables 6 and 7). Focusing on the energy market, energy efficiency interventions are overall more effective than renewable energy policies (Tables 6 and 7).

5. Policy implications

The evidence presented above suggests that regional policies and business orientation shape entrepreneurial initiatives on the environment. However, there is no '*one size fits all*' approach to the sustainability transition of firms. We thus focus on two interlinked policy domains that could be used for fighting climate change.

5.1. Regional policies

The literature highlights the centrality of regional intervention in sustainable transition. In Italy this process was enabled by the 2001 reform of the Italian Constitution, which gave regions the function of enacting specific regulations to achieve goals established by central government. Legislative Decrees 1998/112 and 2004/239 gave regional authorities responsibility for energy markets.

Our results confirm the effectiveness of regional environmental and energy policies in terms of CO_2 emission reduction (Comodi et al., 2012, Sarrica et al., 2018; Baiardi, 2020). This supports the intuitions of Kube et al. (2019), who find that measures implemented by *law*, rather than by *choice*, should potentially have a stronger effect in terms of environmental improvements and cost savings.

Our evidence is also in line with the increasing salience of functional territories and systems in policy (Mendez et al., 2021), which reflects the centrality of local knowledge and responses to differentiated territorial impacts of environmental problems. A direct link between regional and central governments is facilitated by the EU Cohesion Policy, which lays the ground for the rationale of regional policies as part of place-based narratives and instruments (Barca, 2009; Mendez, 2013).

The importance of regional energy policies in reducing industrial emissions also brings the potential economic returns from renewable energies into clear relief (Arbolino et al., 2022). Regional policies can provide firms with a sort of demonstration effect, which encourages firms to follow them (Horbach & Rammer, 2018).

Lastly, an important obstacle for green transition is the high burden of taxation. In Italy, firm profits are taxed not only nationally, but also locally. This makes the implementation of green activities expensive and potentially confusing. For local taxes, it would be helpful for regional authorities to promote greater fiscal flexibility and simpler bureaucracy. This step towards green transition would help non-listed as well as listed companies, as non-listed companies are more sensitive to financial restrictions.

5.2. Policy mix

Climate change is widely perceived as a catastrophic risk, and '*governments are partnering with sub-national entities and investors on initiatives to tackle climate change. Green investment plans could offer a resilience win-win for public and private actors to adapt to and mitigate the impacts of climate change*' (McLennan, 2021, p. 58). Our results support the idea that a policy mix where regional and internal interventions are jointly implemented is a win-win strategy to mitigate climate change. In this perspective, regional actions work as a push/pull mechanism in driving companies to be more environmentally friendly. This implies that cooperation between public and private sectors and the empowerment of actors below and above the nation-state is already taking place (Mendez et al., 2021).

Our results also suggest that regional conditions stimulate non-public actors, such as multinational corporations, to mobilize resources, to make fundamental institutional changes and to diversify across regions (Boschma, 2017; Boschma et al., 2017). It is very important to understand why some regions are more successful than others in green and energy transitions.

However, our findings also show that conflict can arise where a policy mix is used to stimulate the green and energy transitions of listed firms. In these situations, policy-driven change promoted at regional and firm level fails in terms of climate goals. This may be due either to a bias in the competition for scarce public and private resources (Boschma et al., 2017) or to a lack of coordination, time, and scale in policy mix (Scordato et al., 2018). These factors are in fact crucial when the policy domain ranges across science, technology, and innovation, as does sustainable transition.

6. Conclusions

This paper examines the effectiveness of three distinct types of environmental and energy policies on firm pro-environmental measures and initiatives. Our results show that regional policies are effective when environmental performance is measured in terms of CO_2 emissions. So, regional interventions operate as a push/pull mechanism in driving companies to be more environmentally friendly. When moving to consider qualitative indexes as proxies of firm environmental performance, a policy mix is a *win-win* strategy. This finding should help to identify those policy-driven changes which make some regions more successful than others in sustainability transition.

Our analysis has certain limitations, which could be overcome by research in the future. First, according to the literature on sustainable transition (Markard et al., 2012), each policy category can be implemented through different types of regional interventions.

General policies for reducing air emissions consider interventions establishing limits for atmospheric emissions and improvements in environmental technologies, while renewable energy and energy efficiency measures usually entail environmental standards and financial support for specific projects. But available data only allow us to consider these three categories of policy separately and not jointly. We leave for future research the assessment of their joint effects on firm environmental performance.

Second, it would be very interesting to extend this study to more than one European country, although somewhat challenging because policy information is frequently available only on national websites, and knowledge of the local language is often indispensable. To facilitate international cooperation, collaboration and knowledge sharing, the establishment of think tanks and research centers would be helpful. However, since the Non-Financial Reporting Directive 2014/95/EU came into force in 2018, homogeneous data is now available for comparison of listed companies across Europe. A fruitful avenue for future research would be to extend this analysis to listed companies in other countries.

Third, our analysis is based on a sample of Italian listed firms that published environmental disclosure in the time period under investigation. There may be bias in this non-probabilistic selection of the sample, but it can be overcome in the future only if Italian listed companies systematically produce and publish environmental information in their integrated reports and/or on their web-sides.

Moreover, these firms are principally concentrated in the north of Italy. This structural feature does not allow us to completely capture the economic heterogeneity of the twenty regions of Italy. In addition, the north of Italy is also characterized by a strong presence of SMEs, which generate 66.9% of the overall value added in Italy (OECD, 2020). SMEs tend to specialize in different production phases of the same supply chain. The literature shows that geographical proximity matters for the development of new green activities, which can trigger learning and competitiveness effects locally, and encourage adoption by other firms (Beise & Rennings, 2005). However, in developing green initiatives, SMEs differ from larger firms in terms of funding sources, human capital, production processes and public-private partnerships. These differences need to be explored more systematically in future research.

Finally, the Emissions Category Score is based on self-declaration by firms, which may overestimate their environmental efforts, and is not subject to any independent audit control. This potential bias is a further limitation of the paper, which could be overcome in the future only if Italian listed companies systematically require audit firms to certify their environmental and/or integrated reports.

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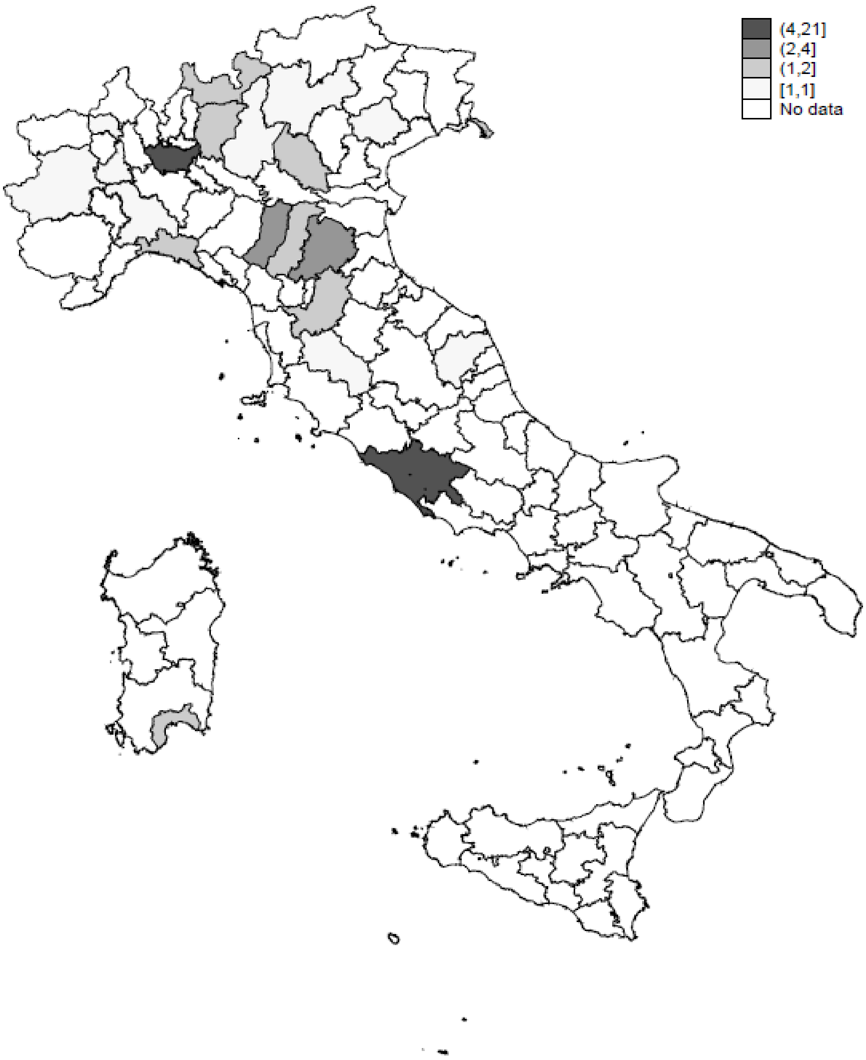
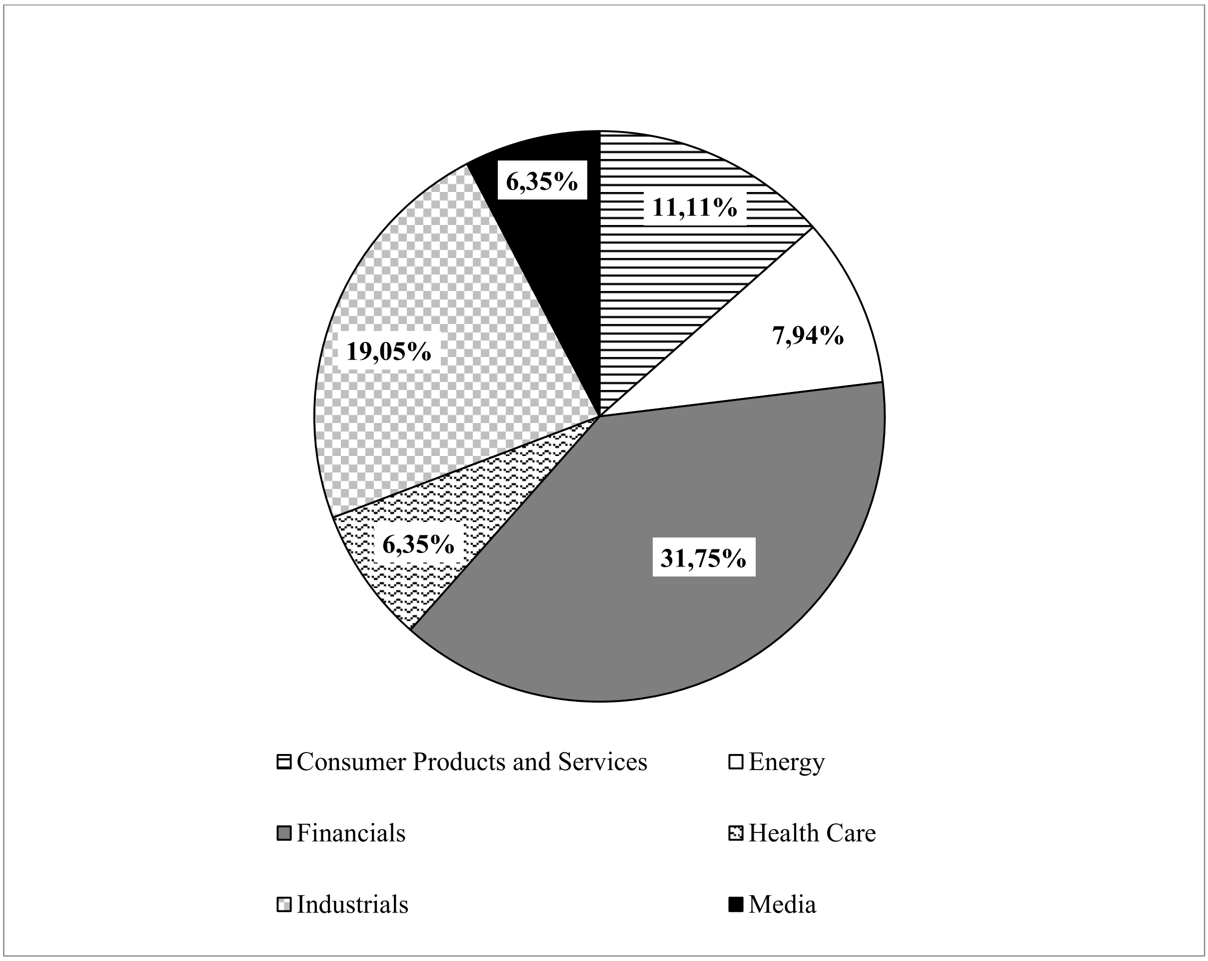
Figures

Figure 1 - The geographical distribution of sample firms by NUTS 3 regions



Notes: Author's elaboration on Refinitiv® Eikon-Datastream

Figure 2 - Sample firms by industry



Notes: Authors' elaborations on Refinitiv® Eikon-Datastream database and Borsa Italiana

Tables

Table 1: Comparison of observable policy adopters' characteristics – Average values for the period 2008-2019

	Macroeconomic conditions		***Firm environmental performance***			***Firm-specific characteristics***		
	Per capita GDP	*Employment*	*CO_2 emissions*	*Emission Category Score*	*Environmental Pillar Score*	*Liquidity*	*Profitability*	*Firm size*
Case (i) - General policies for reducing air emissions								
Regional policy adopters	41,657	1,076,694	51,028	29.19	32.70	6.21	4.51	30,200,000
Regional and internal policy adopters	41,128	1,243,617	7,617,035	83.00	78.43	14.64	8.03	144,000,000
No regional and no firm policy adopters	30,980	499,137	145,793	30.28	31.37	18.62	-51.37	35,800,000
Case (ii) - Renewable energy interventions								
Regional policy adopters	44,102	1,255,281	515,564	24.50	26.90	7.29	8.72	27,700,000
Regional and internal policy adopters	45,653	1,405,277	1,155,868	72.24	75.42	16.48	7.86	113,000,000
No regional and no firm policy adopters	34,236	863,692	-	29.34	29.19	1.21	-21.13	50,900,000
Case (iii) - Energy efficiency interventions								
Regional policy adopters	40,846	1,084,656	1,544,676	28.40	31.96	10.28	11.87	17,200,000
Regional and internal policy adopters	45,477	1,454,480	1,733,244	80.64	77.57	16.28	9.25	162,000,000
No regional and no firm policy adopters	33,580	712,813	-	30.11	30.29	1.41	-19.02	45,600,000

Notes: Author's elaboration on Refinitiv® Eikon-Datastream, ISPRA, Eurostat data. Per capita GDP and Employment are proxied with GDP at current market prices (in Euro per inhabitant) and the number of persons employed in active enterprises in industry, construction and services (except insurance activities of holding companies), respectively. Liquidity, profitability and firm size are proxied by inventories, ROE and total assets respectively.

Table 2: Multinomial logistic regressions – panel fixed effects model

	General policies for reducing air emissions (*Case i)*		***Renewable energy interventions (Case ii)***		***Energy efficiency interventions (Case iii)***	
	Regional policy adopters	**Regional and internal policy adopters**	**Regional policy adopters**	**Regional and internal policy adopters**	**Regional policy adopters**	**Regional and internal policy adopters**
Per capita GDP	3.7491*	1.6474	4.1265***	3.7226***	3.6361***	3.6644***
	(2.2639)	(2.1826)	(0.7297)	(0.5787)	(0.8698)	(0.7464)
Employment	2.0052	0.0684	3.3385***	2.8301***	3.4857***	2.2256***
	(2.0685)	(1.9663)	(0.7391)	(0.5624)	(0.9728)	(0.6964)
Liquidity	-2.1917***	-0.6066	-0.1130	0.7617***	-0.2280	1.4022***
	(0.8039)	(0.6786)	(0.3189)	(0.2347)	(0.3637)	(0.3704)
Profitability	0.5463	0.5176	0.4829*	0.6939**	0.6501**	0.6229
	(0.5128)	(0.4805)	(0.2783)	(0.2973)	(0.3232)	(0.4049)
Firm size	-1.7957	0.4719	-5.5253***	0.1162	-10.8341***	1.6231***
	(1.3897)	(0.8962)	(1.8842)	(0.2749)	(3.3253)	(0.4531)
Constant	2.4985**	3.7171***	-1.1744**	0.5716**	-2.3691**	0.1922
	(1.1477)	(1.0989)	(0.5848)	(0.2830)	(0.9800)	(0.3430)
Observations	108	108	193	193	141	141

Notes: Standard errors are in parentheses. Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01. Explanatory variables are standardized. Per capita GDP and Employment are proxied with GDP at current market prices (in Euro per inhabitant) and the number of persons employed in active enterprises in industry, construction and services (except insurance activities of holding companies), respectively. Liquidity, profitability, and firm size are proxied by inventories, ROE, and total assets respectively. Firm fixed effects are included.

Table 3: Testing the balancing hypothesis in the three policy categories – panel data estimates

		Pseudo R^2	LR χ^2	$p > \chi^2$	Mean Bias	Median Bias	Reduction in bias (%)	Rubin's B test	Rubin's R test
General policies for reducing air emissions									
P_R/P_0	Unmatched	0.051	6.990	0.008	43.500	43.500	-	43.500*	0.020*
	Matched	0.000	0.030	0.867	0.700	0.700	98.400	3.900	1.040
P_{RF}/P_R	Unmatched	0.101	12.490	0.000	78.200	78.200	-	78.200*	0.510
	Matched	0.007	0.049	0.484	17.300	17.300	77.900	19.700	0.610
P_{RF}/P_0	Unmatched	0.002	0.320	0.569	10.500	10.500	-	10.500	0.230*
	Matched	0.000	0.030	0.874	1.900	1.900	82.300	2.800	0.740
Renewable energy policies									
P_R/P_0	Unmatched	0.028	3.220	0.073	49.200	49.200	-	49.200*	0.490*
	Matched	0.000	0.000	0.994	0.200	0.200	99.600	0.300	1.010
P_{RF}/P_R	Unmatched	0.039	4.870	0.027	47.900	47.900	-	47.900*	0.710
	Matched	0.091	5.220	0.022	68.400	68.400	97.700	74.300*	0.810
P_{RF}/P_0	Unmatched	0.133	25.860	0.000	100.200	100.200	-	100.200*	0.480*
	Matched	0.000	0.000	0.998	0.100	0.100	99.900	0.100	0.980
Energy efficiency policies									
P_R/P_0	Unmatched	0.098	13.260	0.000	87.300	87.300	-	87.300*	0.390*
	Matched	0.000	0.000	0.983	0.400	0.400	99.500	0.600	0.980
P_{RF}/P_R	Unmatched	0.028	4.940	0.026	41.800	41.800	-	41.800*	0.390*
	Matched	0.000	0.000	0.990	0.200	0.200	99.500	0.300	1.010
P_{RF}/P_0	Unmatched	0.223	38.960	0.000	127.600	127.600	-	127.600*	0.780
	Matched	0.000	0.000	0.980	0.500	0.500	99.600	0.600	0.990

Notes: The results of these tests are the same independently of the three dependent variables used in the empirical analysis. An asterisk is shown next to Rubin's B test if it is greater than 25% and Rubin's R test if its values fall outside the interval [0.5; 2]. These tests are computed with reference to results reported in Tables 5-7.

Table 4: Global spatial autocorrelation analysis

	General policies for reducing air emissions (Case *i*)		Renewable energy policies (Case *ii*)		Energy efficiency policies (Case *iii*)	
	P_R	P_{RF}	P_R	P_{RF}	P_R	P_{RF}
Moran's *I* statistics	-0.002	-0.023	-0.028	-0.082	-0.041	0.058
z	0.433	-0.924	-1.303	-7.315	-0.735	1.152
p-value	0.333	0.178	0.096	0.000	0.231	0.125
Geary's *c* statistics	0.981	0.989	0.998	0.988	0.97	1.026
z	-0.243	-0.708	-0.018	-0.183	-0.312	0.504
p-value	0.404	0.239	0.493	0.428	0.378	0.307
Getis and Ord's *G* statistics	0.583	0.790	0.6	0.164	0.524	0.583
z	-1.131	0.893	-0.702	-0.714	-1.304	-1.060
p-value	0.129	0.163	0.241	0.238	0.096	0.289

Notes: The table reports the statistics, the z-value and the associated p-value of three global spatial autocorrelation statistics: Moran's I, Geary's c, and Getis and Ord's G tests. These tests investigate how the values of a variable are related, on the basis of their location. The greatest Euclidean distance between provinces where firms have their headquarters is computed using their latitude and longitude. The Euclidean distance (equal to 26.52) is used to generate a weight matrix capturing distances between provinces, which is employed in the computation of the three tests.

Table 5: The multiple treatment effects of environmental and energy policies on CO_2 emissions – panel data estimates

Treated/control	***Case (i)*** ***General policies for reducing air emissions***	***Case (ii)*** ***Renewable energy interventions***	***Case (iii)*** ***Energy efficiency interventions***
P_R/P_0	-2.0982**	-2.2621***	-3.7675***
	(0.9468)	(0.6957)	(1.1287)
P_{RF}/P_R	1.1951**	-2.7970***	-6.7247***
	(0.5362)	(0.8353)	(1.6915)
P_{RF}/P_0	1.1977**	-2.3516***	-3.2929***
	(0.5362)	(0.8284)	(1.2158)

Notes: The estimated treatment effects are reported as a percentage of the untreated outcome means. Robust standard errors are in parentheses. Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01. The number of neighbors is 5 and a caliper width of 0.20 is used with the following exceptions: caliper width equal 0.25 and 0.30 in Cases (ii) and (iii) for P_R/P_0; caliper width equal to 0.40 in Case (ii) for P_{RF}/P_R; caliper width equal to 0.30 and 0.70 in Cases (ii) and (iii) for P_{RF}/P_0. The estimated treatment effects are computed by using propensity scores obtained from results shown in Table 2.

Table 6: The multiple treatment effects of environmental and energy policies on the Emission Category Score – panel data estimates

Treated/control	***Case (i)*** ***General policies for reducing air emissions***	***Case (ii)*** ***Renewable energy interventions***	***Case (iii)*** ***Energy efficiency interventions***
P_R/P_0	-0.8559***	-0.5617***	-0.6338***
	(0.0562)	(0.0672)	(0.0736)
P_{RF}/P_R	0.9536***	0.4709***	0.4950***
	(0.0420)	(0.0744)	(0.1057)
P_{RF}/P_0	0.9207***	0.4228***	0.6913***
	(0.0478)	(0.1081)	(0.0650)

Notes: The estimated treatment effects are reported as a percentage of the untreated outcome means. Robust standard errors are in parentheses Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01. The number of neighbors is 5 and a caliper width of 0.20 is used with the following exceptions: caliper width equal to 0.25 in Case (i) for P_{RF}/P_R, and Case (iii) for P_R/P_0; caliper width equal to 0.30 and 0.35 in Cases (i) and (ii) for P_R/P_0, respectively; caliper width equal to 0.65 in Case (iii) for P_{RF}/P_0. The estimated treatment effects are computed by using propensity scores obtained from results shown in Table 2.

Table 7: The multiple treatment effects of environmental and energy policies on Environmental Pillar Score – panel data estimates

Treated/control	***Case (i)*** ***General policies for reducing air emissions***	***Case (ii)*** ***Renewable energy interventions***	***Case (iii)*** ***Energy efficiency interventions***
P_R/P_0	-0.6796***	-0.5335***	-0.5509***
	(0.0449)	(0.0377)	(0.0558)
P_{RF}/P_R	0.7728***	0.4079***	0.3809***
	(0.0451)	(0.0581)	(0.0515)
P_{RF}/P_0	0.7407***	0.3760***	0.4593***
	(0.0467)	(0.0789)	(0.0630)

Notes: The estimated treatment effects are reported as a percentage of the untreated outcome means. Robust standard errors are in parentheses. Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01. The number of neighbors is 5 and a caliper width of 0.20 is used with the following exceptions: caliper width equal to 0.25 in Case (ii) for P_R/P_0; caliper width equal to 0.30 in Cases (i) and (iii) for P_R/P_0; caliper width equal to 0.45, 0.40 and 0.55 in Cases (i), (ii) and (iii) for P_{RF}/P_0, respectively. The estimated treatment effects are computed by using propensity scores obtained from results shown in Table 2.

Appendix A

Data description: regional and firm policy variables

Regional policies are built by collecting the qualitative information provided in the database `*Air quality improvement measures*', compiled by the Italian Institute for Environmental Protection and Research (ISPRA). It contains data provided annually by Regions and Autonomous Provinces since 2005, to comply with national and European legislation on air quality improvement plans.

The following information is available, in Italian: the year and the region where the policy is implemented, the sector where it is applied and a detailed description of regional measures (including in addition to those already provided at the national level). We considered the years 2008-2011.

We proceed as follows. First, we select the sector to investigate, i.e., the industrial sector. We then select policies with the following codes (*codice misura*): (i) '*Controllo emissioni impianti industriali*' (Industrial plant emissions control), (ii) '*Fonti energetiche rinnovabili*' (Renewable energy sources) and (iii) '*Fonti energetiche tradizionali*' (Traditional energy sources). These three policy categories cover different measures, as reported in Tables A1-A3. For the sake of simplicity, we call Case (i) 'General policy for reducing air emissions', Case (ii) 'Renewable energy policies' and Case (iii) 'Energy efficiency policies'.

Next, a dummy variable is constructed for each policy category, equal to 1 if the policy was applied in a region in each of the years 2008, 2009, 2010 and 2011 and 0 otherwise. There are missing values for the years 2012-2019.

The next step is to take into consideration firm policies. In this case, data are retrieved from Refinitiv® Eikon-Datastream, Section ESG Scores. Data are available for the years 2008-2019. We consider the variables '*Policy Emissions*', '*Resource Reduction Policy*' and '*Policy Energy Efficiency*', which are voluntary actions corresponding to three types of policy (i)-(iii) implemented on a regional scale. These are qualitative variables, taking values of '*True*' or '*False*'. The dummy variable is thus equal to 1 if '*True*' and 0 otherwise.

Next, for each type of policy, we merge the observations provided by these two distinct variables to yield a treatment indicator used to estimate propensity scores. This series is an ordinal variable, which, as reported in Table A4 in Appendix A, takes the value of 0 if no regional and no firm policy has been applied (P_0), 1 if only regional policy has been implemented (P_R) and 2 if both regional and internal policies have been applied (P_{RF}) in the years 2008-2011. Missing records are reported in all the other cases and in the remaining years.

Lastly, for each policy category, we compute three distinct dummies corresponding to status 1 and status 2 of this treatment indicator.[12] These three sets of dummies are then used to estimate the average treatment effects reported in Section 4.

[12] Note that these dummies may differ from the initial regional and firm specific policy dummies. Consider for example the variable obtained when the treatment indicator is equal to 1. In this context, a value of 1 in a specific year indicates that only regional policy has been applied, and that no internal policy has been applied in that time period, while a value of 0 indicates that no regional policy and no firm policy have been applied.

Table A1 – Policy measure: *'Controllo emissioni impianti industriali'* (Industrial plant emission control) 2008-2011

Region	**Policy name (IT)**	**Policy name (EN)**
Emilia Romagna	Interventi per ridurre le emissioni del settore industriale	Interventions to reduce emissions from the industrial sector
Friuli Venezia Giulia	Protocolli di intesa	Memoranda of understanding
Lazio	Investimenti per monitoraggio inquinanti	Investments for pollutant monitoring
Liguria	Limiti di emissione cautelativi per impianti IPPC in Provincia di Savona	Precautionary emission limits for IPPC plants in the Province of Savona
	Chiusura progressiva della centrale ENEL di Genova	Gradual closure of the ENEL power station in Genoa
	Interventi nell'ambito dei provvedimenti di autorizzazione integrata ambientale a stabilimenti produttivi	Interventions in the context of integrated environmental authorization measures for production plants
	Interventi per il contenimento di emissioni diffuse di polveri dai parchi carbone	Interventions for limiting emissions from coal parks
Lombardy	Migliori tecnologie di abbattimento disponibili per la riduzione dell'inquinamento atmosferico per alcune attività produttive	Best abatement technologies available for the reduction of atmospheric pollution for some production activities
	Riduzione emissioni dagli impianti del comparto "legno truciolare"	Reduction of emissions from plants in the chipboard sector
	Allegato tecnico settore plastica e gomma	Technical annex for the plastic and rubber sector
	Prescrizioni tecniche per il contenimento delle emissioni dagli impianti produttivi appartenenti al comparto dell'acciaio	Technical requirements for limiting emissions from production plants in the steel sector
	Limiti emissione centrali turbogas	Turbogas plant emission limits
	Creazione di una rete di raccolta, elaborazione e archiviazione dati SME di grandi impianti	Creation of collection, processing and storage network of large plants
	Limiti emissioni da impianti e attività a ridotto impatto ambientale	Emission limits from plants and activities with low environmental impact
Piedmont	Riduzione emissioni nel trasporto materie prime e prodotti delle attività produttive	Reduction of emissions in the transport of raw materials and manufacturing products
	Autorizzazione emissioni	Emission authorization
Veneto	Accordo di programma per la Chimica a Porto Marghera e realizzazione del sistema integrato di monitoraggio ambientale e gestione delle emergenze (progetto SIMAGE)	Chemicals program agreement in Porto Marghera and implementation of the integrated environmental monitoring and emergency management system (SIMAGE project)

Notes: Author's elaboration on ISPRA data.

Table A2 – Policy measure: '*Fonti energetiche rinnovabili*' (Renewable energy sources) 2008-2011

Region	**Policy name (IT)**	**Policy name (EN)**
Lombardy	Fonti energetiche rinnovabili	Renewable energy sources
	Bando T R E N D - TECNOLOGIA E INNOVAZIONE PER IL RISPARMIO E L'EFFICIENZA ENERGETICA DIFFUSA	TREND Call: Technology and innovation for energy savings
Marche	Sostegno al ricorso alle fonti rinnovabili nel settore industriale e nelle imprese	Support for the use of renewable sources in the industrial sector and in firms

Notes: Author's elaboration on ISPRA data.

Table A3 – Policy measure: '*Fonti energetiche tradizionali'* (Traditional energy sources) 2008-2011

Region	**Policy name (IT)**	**Policy name (EN)**
Lombardy	Bando per teleriscaldamento urbano	Call for urban district heating
Liguria	Patto dei Sindaci in tema di energia e cambiamento climatico	Mayors' Agreement on energy and climate change
Marche	Finanziamento progetti per la gestione integrata degli impatti ambientali in aree produttive significative e per l'efficienza energetica	Project funding for the integrated management of environmental impacts in significant production areas and for energy efficiency
	Sostegno agli investimenti eco-innovativi nelle PMI	Support for eco-innovative investments in SMEs
	Sostegno agli investimenti finalizzati al risparmio energetico e alla produzione di energia da fonti rinnovabili da utilizzare in contesti produttivi	Support for investments in energy saving and the production of energy from renewable sources to be used in manufacturing
Piedmont	Teleriscaldamento	District heating

Notes: Author's elaboration on ISPRA data.

Table A4 – Treatment indicator for each policy category (*i*)-(*iii*)

Policy group	***Value***	***Data Source***
		Case (i) - General policies for reducing air emissions
P_0	0	*No regional and no firm policies*
P_R	1	'Industrial plant emissions control' from ISPRA
$P_{R,F}$	2	'Industrial plant emissions control' from ISPRA and 'Policy Emissions' from Thomson Reuters Datastream
		Case (ii) - Renewable energy interventions
P_0	0	*No regional and no firm policies*
P_R	1	'Renewable energy policies' from ISPRA
$P_{R,F}$	2	'Renewable energy policies' from ISPRA and 'Resource Reduction Policy' from Thomson Reuters Datastream
		Case (iii) - Energy efficiency interventions
P_0	0	*No regional and no firm policies*
P_R	1	'Energy efficiency sources' from ISPRA
$P_{R,F}$	2	'Energy efficiency sources' from ISPRA and 'Policy Energy Efficiency' from Thomson Reuters Datastream

Note: The data source is shown for policy categories (*i*), (*ii*) and (*iii*) for each value of the treatment indicator.

Appendix B

Table B1: Robustness check: multinomial probit regressions – panel fixed effect model

	General policies for reducing air emissions (*Case i*)		***Renewable energy interventions (Case ii)***		***Energy efficiency interventions (Case iii)***	
	Regional policy adopters	**Regional and internal policy adopters**	**Regional policy adopters**	**Regional and internal policy adopters**	**Regional policy adopters**	**Regional and internal policy adopters**
Per capita GDP	2.7744*	1.0157	3.1688***	2.9195***	2.4740***	2.8522***
	(1.4176)	(1.3337)	(0.5317)	(0.4164)	(0.6095)	(0.5668)
Employment	1.5419	-0.0725	2.5074***	2.1782***	2.1430***	1.8098***
	(1.3033)	(1.2098)	(0.5348)	(0.4116)	(0.6359)	(0.5453)
Liquidity	-1.6415***	-0.3354	-0.1029	0.6111***	-0.0025	0.0705***
	(0.5499)	(0.4366)	(0.2469)	(0.1848)	(0.0171)	(0.0178)
Profitability	0.4254	0.4102	0.3438	0.4594**	0.4815*	0.4794
	(0.4209)	(0.3958)	(0.2235)	(0.2080)	(0.2589)	(0.2978)
Firm size	-1.3195	0.4951	-4.1877***	0.0831	-5.8645***	1.1916***
	(1.0182)	(0.6311)	(1.3760)	(0.2218)	(1.7311)	(0.3474)
Constant	1.5720**	2.5797***	-0.9456**	0.3883*	-1.1029**	-0.7169**
	(0.7089)	(0.6717)	(0.4108)	(0.2061)	(0.4308)	(0.3115)
Observations	108	108	193	193	141	141

Notes: Standard errors are in parentheses. Significance levels: $^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Per capita GDP and Employment are proxied with GDP at current market prices (in Euro per inhabitant) and the number of persons employed in active enterprises in industry, construction and services (except insurance activities of holding companies), respectively. Explanatory variables are standardized. Liquidity, profitability and firm size are proxied by means of inventories, ROE and total assets. Firm fixed effects are included.

Table B2: Robustness check: the multiple treatment effects of environmental and energy policies on CO_2 emissions – panel data estimates

Treated/control	***Case (i)*** ***General policies for reducing air emissions***	***Case (ii)*** ***Renewable energy interventions***	***Case (iii)*** ***Energy efficiency interventions***
P_R/P_0	-1.1971**	-1.3447***	-1.9623**
	(0.5364)	(0.3894)	(0.6381)
P_{RF}/P_R	1.1854**	-1.5289**	-2.3021***
	(0.5362)	(0.5358)	(0.7738)
P_{RF}/P_0	1.2019**	-1.1458***	-2.0371*
	(0.5362)	(0.3978)	(0.7199)

Notes: The estimated treatment effects are reported as a percentage of the untreated outcome means. Robust standard errors are in parentheses. Significance levels: $^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. The number of neighbors is 1 and no caliper has been used. The estimated treatment effects are computed by using propensity scores obtained from results shown in Table B1.

Table B3: Robustness check: the multiple treatment effects of environmental and energy policies on the Emission Category Score - panel data estimates

Treated/control	*Case (i)* *General policies for reducing air emissions*	*Case (ii)* *Renewable energy interventions*	*Case (iii)* *Energy efficiency interventions*
P_R/P_0	-0.8897***	-0.6245***	-0.6490***
	(0.0547)	(0.0564)	(0.0846)
P_{RF}/P_R	0.8970***	0.4859***	0.4811***
	(0.0526)	(0.0857)	(0.1077)
P_{RF}/P_0	0.9153***	0.3729**	0.6905***
	(0.0497)	(0.1711)	(0.0691)

Notes: The estimated treatment effects are reported as a percentage of the untreated outcome means. Robust standard errors are in parentheses. Significance levels: *p < 0.1, **p < 0.05, ***p < 0.01. The number of neighbors is 1 and no caliper has been used. The estimated treatment effects are computed by using propensity scores obtained from results shown in Table B1.

Table B4: Robustness check: the multiple treatment effects of environmental and energy policies applied at regional level and at firm level (alternatively or jointly) on Environmental Pillar Score - panel data estimates

Treated/control	*Case (i)* *General policies for reducing air emissions*	*Case (ii)* *Renewable energy interventions*	*Case (iii)* *Energy efficiency interventions*
P_R/P_0	-0.7121***	-0.5608***	-0.6041***
	(0.0629)	(0.0370)	(0.0598)
P_{RF}/P_R	0.7230***	0.4016***	0.4364***
	(0.0468)	(0.0621)	(0.0695)
P_{RF}/P_0	0.7415***	0.2862**	0.5057***
	(0.0604)	(0.1428)	(0.0514)

Notes: The estimated treatment effects are reported as a percentage of the untreated outcome means. Robust standard errors are in parentheses. Significance levels: *p < 0.1, **p < 0.05, ***p < 0.01. The number of neighbors is 1 and no caliper has been used. The estimated treatment effects are computed by using propensity scores obtained from results shown in Table B1.

Table B5: Testing the balancing hypothesis using a number of neighbors equal to 1 with no caliper widths – panel data estimates

		Pseudo R^2	LR χ^2	$p > \chi^2$	Mean Bias	Median Bias	Reduction in bias %	Rubin's B test	Rubin's R test
General policies for reducing air emissions									
P_R/P_0	Unmatched	0.046	6.330	0.012	43.200	43.200	-	43.200*	0.020*
	Matched	0.000	0.000	0.986	0.100	0.100	99.800	0.400	1.010
P_{RF}/P_R	Unmatched	0.186	26.670	0.000	113.100	113.100	-	113.100*	0.990
	Matched	0.000	0.000	0.951	1.100	1.100	99.000	1.100	0.980
P_{RF}/P_0	Unmatched	0.002	0.270	0.604	9.700	9.700	-	9.700	0.280*
	Matched	0.000	0.000	0.948	0.800	0.800	91.500	1.200	0.780
Renewable energy policies									
P_R/P_0	Unmatched	0.025	2.860	0.091	45.900	45.900	-	45.900*	0.054
	Matched	0.000	0.000	0.995	0.200	0.200	99.600	0.200	1.000
P_{RF}/P_R	Unmatched	0.024	4.740	0.029	39.300	39.300	-	39.300*	1.070
	Matched	0.000	0.000	0.993	0.200	0.200	99.500	0.200	1.000
P_{RF}/P_0	Unmatched	0.133	25.930	0.000	100.600	100.600	-	100.600*	0.490*
	Matched	0.000	0.000	0.967	0.700	0.700	99.300	0.900	1.000
Energy efficiency policies									
P_R/P_0	Unmatched	0.071	9.570	0.002	72.300	72.300	-	72.300*	0.520
	Matched	0.000	0.000	0.973	0.800	0.800	98.900	0.900	0.990
P_{RF}/P_R	Unmatched	0.013	2.350	0.125	28.500	28.500	-	28.500*	0.510
	Matched	0.000	0.000	0.998	0.000	0.000	99.800	0.100	0.980
P_{RF}/P_0	Unmatched	0.225	39.320	0.000	128.200	128.200	-	128.200*	0.870
	Matched	0.000	0.000	0.989	0.300	0.300	99.800	0.300	0.990

Notes: The results of these tests are the same independently of the three dependent variables used in the empirical analysis. An asterisk is shown next to Rubin's B test if it is greater than 25% and Rubin's R test if its values fall outside the interval [0.5; 2]. These tests are computed with reference to results reported in Tables B2-B4.

Table B6: Robustness check: multinomial logit regressions – cross section estimates

	General policies for reducing air emissions (*Case i*)		*Renewable energy interventions (Case ii)*		*Energy efficiency interventions (Case iii)*	
	Regional policy adopters	**Regional and internal policy adopters**	**Regional policy adopters**	**Regional and internal policy adopters**	**Regional policy adopters**	**Regional and internal policy adopters**
Per capita GDP	3.7986*	4.2149**	1.1461**	1.8463***	0.5341	1.3394***
	(2.1056)	(2.1173)	(0.5827)	(0.5869)	(0.4884)	(0.4821)
Employment	3.7273	5.6375**	-1.1320	-0.0226	0.9541	1.6352
	(2.2801)	(2.3272)	(1.5327)	(1.3688)	(1.2214)	(1.2894)
Liquidity	-0.8052	-0.5306	-0.4280	0.7902	-0.4195	0.5730
	(0.6549)	(0.6973)	(0.6375)	(0.6302)	(0.5467)	(0.5819)
Profitability	-0.2615	-0.2789	0.4977	-0.3400	0.4399	-0.2424
	(0.9199)	(0.9397)	(0.8074)	(0.7101)	(0.7455)	(0.6876)
Firm size	-1.2142	1.9871	-0.8390	0.8892	-1.9230	1.2282
	(2.6924)	(1.8282)	(2.5411)	(1.6145)	(2.8323)	(1.7733)
Constant	5.2202	7.3024**	-1.5041	-0.2218	0.1631	1.4968
	(3.3839)	(3.3004)	(1.3325)	(1.0211)	(1.2366)	(1.0252)
Observations	51	51	39	39	41	41

Notes: Standard errors are in parentheses. Significance levels: *p < 0.1, **p < 0.05, ***p < 0.01. Explanatory variables are standardized. Per capita GDP and Employment are proxied with GDP at current market prices (in Euro per inhabitant) and the number of persons employed in active enterprises in industry, construction and services (except insurance activities of holding companies), respectively. Liquidity, profitability and firm size are proxied by means of inventories, ROE and total assets.

Table B7: Robustness check: the multiple treatment effects of environmental and energy policies on CO_2 emissions – cross section estimates

Treated/control	*Case (i)* *General policies for reducing air emissions*	*Case (ii)* *Renewable energy interventions*	*Case (iii)* *Energy efficiency interventions*
P_R/P_0	-1.1434*	-0.1549	-0.3289*
	(0.6495)	(0.2897)	(0.1774)
P_{RF}/P_R	1.7812**	-0.0891	0.9299
	(0.8452)	(0.1015)	(0.5746)
P_{RF}/P_0	1.7445*	-0.1188	0.8753**
	(0.9240)	(0.0985)	(0.4025)

Notes: The estimated treatment effects are reported as a percentage of the untreated outcome means. Robust standard errors are in parentheses. Significance levels: *p < 0.1, **p < 0.05, ***p < 0.01. Liquidity, profitability and firm size are proxied by inventories, ROE and total assets. The number of neighbors is 5 and a caliper width of 0.20 is used with the following exceptions: caliper width of 0.25 in Case (ii) for P_{RF}/P_R; caliper width of 0.30 in Case (i) for P_{RF}/P_R and Case (ii) for P_R/P_0; caliper width of 0.40 in Case (ii) for P_{RF}/P_0; caliper width of 0.45 in Case (i) for P_{RF}/P_0; caliper width of 0.60 in Cases (i) and (iii) for P_{RF}/P_0. The estimated treatment effects are computed by using propensity scores obtained from results shown in Table B6.

Table B8: Robustness check: the multiple treatment effects of environmental and energy policies on the Emission Category Score – cross section estimates

Treated/control	***Case (i)*** ***General policies for reducing air emissions***	***Case (ii)*** ***Renewable energy interventions***	***Case (iii)*** ***Energy efficiency interventions***
P_R/P_0	-0.3600***	-0.1549	-0.2247
	(0.1268)	(0.2897)	(0.2476)
P_{RF}/P_R	0.4038***	0.3022***	0.1666
	(0.1060)	(0.0997)	(0.1473)
P_{RF}/P_0	0.3439***	0.2968***	0.1572
	(0.1325)	(0.1028)	(0.1229)

Notes: The estimated treatment effects are reported as a percentage of the untreated outcome means. Robust standard errors are in parentheses. Significance levels: *p < 0.1, **p < 0.05, ***p < 0.01. The number of neighbors is 5 and a caliper width of 0.20 is used with the following exceptions: caliper width of 0.30 in Case (i) for P_{RF}/P_R and Case (ii) for P_R/P_0; caliper width of 0.35 in Case (ii) for P_{RF}/P_0; caliper width of 0.40 in Case (iii) for P_{RF}/P_0; caliper width of 0.60 in Case (i) for P_{RF}/P_0. The estimated treatment effects are computed by using propensity scores obtained from results shown in Table B6.

Table B9: Robustness check: The multiple treatment effects of environmental and energy policies on Environmental Pillar Score – cross section estimates

Treated/control	***Case (i)*** ***General policies for reducing air emissions***	***Case (ii)*** ***Renewable energy interventions***	***Case (iii)*** ***Energy efficiency interventions***
P_R/P_0	-0.3139***	-0.1761	-0.2371
	(0.0883)	(0.1577)	(0.1809)
P_{RF}/P_R	0.3520***	0.3342***	0.1930*
	(0.0676)	(0.0700)	(0.1131)
P_{RF}/P_0	0.3302***	0.3185***	0.2034***
	(0.0810)	(0.0804)	(0.0796)

Notes: The estimated treatment effects are reported as a percentage of the untreated outcome means. Robust standard errors are in parentheses. Significance levels: *p < 0.1, **p < 0.05, ***p < 0.01. The number of neighbors is 5 and a caliper width of 0.20 is used with the following exceptions: caliper width of 0.25 in Case (ii) for P_R/P_0; caliper width of 0.35 in Case (ii) for P_{RF}/P_0; caliper width of 0.40 in Case (iii) for P_{RF}/P_0; caliper width of 0.60 in Case (i) for P_{RF}/P_0. The estimated treatment effects are computed by using propensity scores obtained from results shown in Table B6.

Table B10: Testing the balancing hypothesis – cross section estimates

		Pseudo R^2	LR χ^2	$p > \chi^2$	Mean Bias	Median Bias	Reduction in bias %	Rubin's B test	Rubin's R test
General policies for reducing air emissions									
P_R/P_0	Unmatched	0.048	2.140	0.143	58.400	58.400	-	58.400*	0.320*
	Matched	0.000	0.010	0.922	3.200	3.200	94.500	4.600	1.040
P_{RF}/P_R	Unmatched	0.041	2.860	0.091	47.500	47.500	-	47.500*	1.700
	Matched	0.000	0.010	0.910	3.200	3.200	93.300	4.000	1.070
P_{RF}/P_0	Unmatched	0.190	13.100	0.000	106.300	106.300	-	106.300*	0.100*
	Matched	0.001	0.030	0.871	2.500	2.500	97.700	5.300	0.840
Renewable energy policies									
P_R/P_0	Unmatched	0.004	0.130	0.722	15.600	15.600	-	15.600	1.440
	Matched	0.000	0.000	0.963	2.900	2.900	81.700	2.600	1.030
P_{RF}/P_R	Unmatched	0.028	1.250	0.263	39.300	39.300	-	39.300*	0.960
	Matched	0.000	0.000	0.995	0.300	0.300	99.300	0.300	1.440
P_{RF}/P_0	Unmatched	0.117	5.180	0.023	85.100	85.100	-	85.100*	1.210
	Matched	0.000	0.000	0.984	1.000	1.000	98.900	1.100	0.990
Energy efficiency policies									
P_R/P_0	Unmatched	0.007	0.260	0.613	21.600	21.600	-	21.600	1.010
	Matched	0.000	0.000	0.967	2.200	2.200	89.800	2.200	0.980
P_{RF}/P_R	Unmatched	0.163	8.600	0.003	98.700	98.700	-	98.700*	0.770
	Matched	0.005	0.170	0.677	12.300	12.300	87.500	16.300	1.350
P_{RF}/P_0	Unmatched	0.090	4.720	0.030	72.600	72.600	-	72.600*	0.980
	Matched	0.000	0.000	0.965	2.000	2.000	97.200	2.000	1.010

Notes: The results of these tests are the same independently of the three dependent variables used in the empirical analysis. An asterisk is shown next to Rubin's B test if it is greater than 25% and Rubin's R test if its values fall outside the interval [0.5; 2]. These tests are computed with reference to results reported in Tables B7-B9.