Do sustainable energy policies matter for reducing air pollution?

Donatella Baiardi
(University of Parma)

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Overview

- Introduction
- Aim of the paper
- A general overview of environmental quality and energy scenario in Italy
- Methodological framework
- Data
- Results
- Discussion and conclusions

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Introduction

- Nowadays, sustainable energy is at the heart of economic growth and the climate change agenda;

- Attention to the environment and the awareness of the need to mitigate climate changes has led the policymaker to discourage the use of fossil energy sources, such as oil, natural gas and coal, and to encourage an efficient use of the existing energy sources in almost all countries in the world during the last few decades;

- According to RISE (2018), sustainable energy policies ***matter*** for the successful realization of this transition.

Introduction: The Italian case

- Italy is an interesting case of study for many reasons:
  - It is the eighth-largest emitter of greenhouse emissions (GHG) in the OECD and the fourth-largest in the European Union;
  - The energy sector is the largest contributor to national total GHG emissions with a share equal to 82.4 per cent in 2012;
  - It has experienced an extraordinary growth in the renewable energy sector since 2009, with the share of renewables in total final consumption that rose from 10 to 13.5 per cent from 2010 to 2013;

Introduction: The Italian case

- Many efforts have been made to reduce air pollution:

  - The reform of the Italian Constitution in 2001, which gave greater policy autonomy to Regions and local authorities;

  → The importance of local authorities in terms of energy policy planning has been widely investigated in the literature (Comodi et al., *Energy Policy*, 2012; Bellocchi et al., *Energy,* 2018; Sarrica et al., *Energy Policy*, 2018)

  - a national GHG emissions reduction plan was adopted in 2002, and updated in 2012;
  - the National Energy Strategy was established in 2013 with the aim of reducing energy costs and meeting environmental targets.

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The aim of the paper

- The aim of this paper is to assess the impact of sustainable energy policies on air emissions in the case of the 110 Italian provinces.

- We focus our attention only on ***energy efficiency*** and ***renewable resource measures*** implemented in the years 2005-2010 on a ***local***, or ***regional*** or ***local and regional scale***;

- We investigate their potential different effects on *different proxies of air pollution*., i.e. carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O), Non-methane Volatile Organic Compounds (NMVOCs), nitrogen oxides (NO_x) and sulphur dioxide (SO_2)

The aim of the paper

❖ ***Policy variables – details***

- With regard to energy efficiency policies, we consider those interventions, implemented on a local or regional level in the years 2005-2010, whose aim is to promote district heating, wood biomass district heating and energy savings. As noted above, energy efficiency measures are the priority according to the EU Directive;
- With regard to renewable resource policies, we consider those interventions, implemented at local or regional level in the years 2005-2010, which provide incentives for the installation of photovoltaic and solar systems, and the promotion of renewable energy (wind, solar energy and so on) in the industrial and public sectors.

The aim of the paper

- Two novel datasets have been employed in the empirical analysis:
  - Data on air pollutants are provided by `*Invetaria*', a database retrieved by the Italian Institute for Environmental Protection and Research (ISPRA);
  - Policy variables are built on the basis of the information obtained from another database provided by ISPRA named `Air quality improvement measures' → we focus only on energy efficiency and renewable resource measures implemented in the years 2005-2010 on a local, or regional or local and regional scale;
  - To the best of our knowledge, these data have not yet been studied in the literature.

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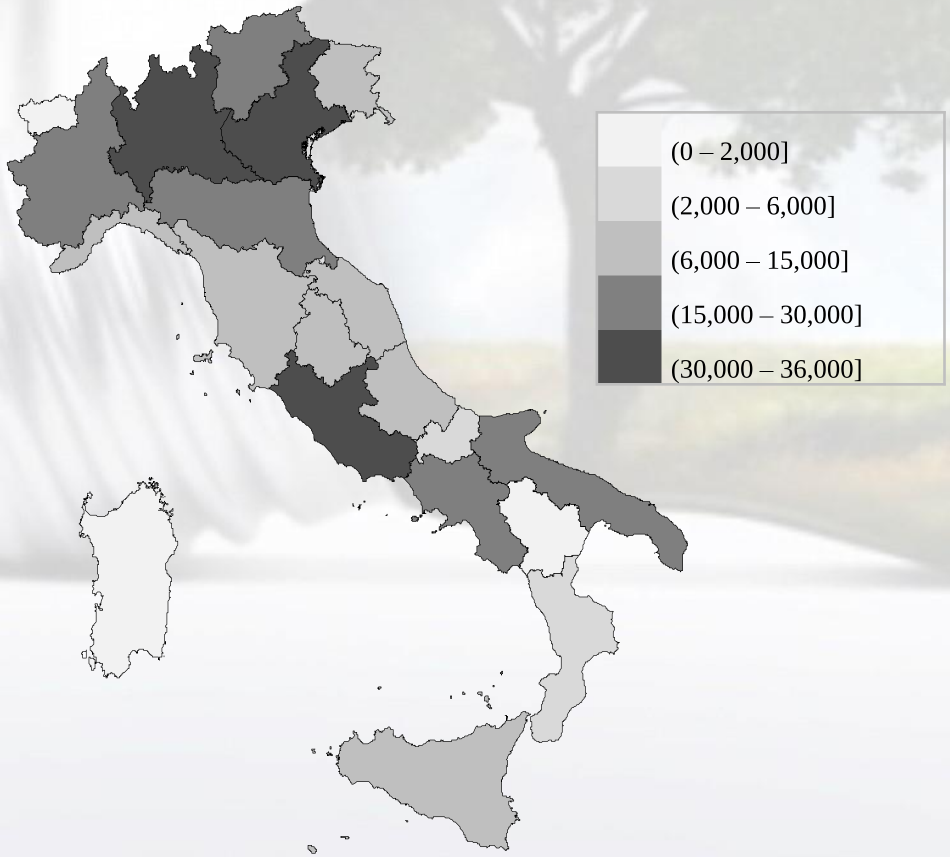
Environmental quality in Italy

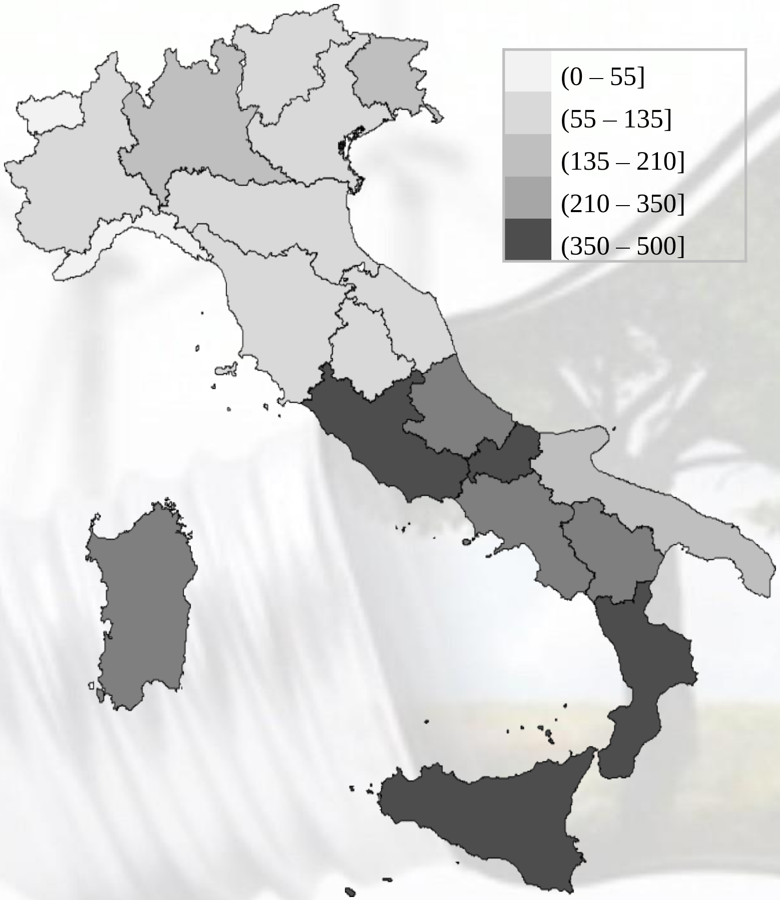
- In general, Lombardy, Emilia Romagna, Veneto and Lazio exhibit the highest concentration of the emissions of global pollutants, which, in most of cases, are double than the national average.

Figure 1: CO_2 emissions in 2015



For example, CO_2 emissions in these regions are equal to 35,504, 27,373, 32,160 and 35,324 and the national average is 14,826 in 2015. Similar trends are observed for all the other gases.

Figure 2: NMVOCs emissions in 2015



NMVOCs, instead, are the only gases in the sample which exhibit higher levels in Southern than Northern regions.

- In general, SO2, NOx and CO2 present a yearly average contraction equal to 7.79, 4.60 and 4.07 per cent, respectively, in the years 2005-2015, while the remaining gases record a decrease on average of about 2 per cent in the same time period.

Sustainable energy policies in Italy

- The legislative framework for energy policies has considerably changed during recent decades;

- It is constituted by the intersection of four distinct levels;

- The highest level is the European Union directives, which are then transposed and implemented at national level.

- At national level, in the light of the principle of subsidiarity, the responsibility of the implementation of energy policies is attributed to Regions, Provinces, and Municipalities, with State determining the fundamental principles;

- Regions and Autonomous Provinces legislate in compliance with state guidelines.

Sustainable energy policies in Italy

- In particular, Regional Policy is fundamental to meeting the goals of the Europe 2020 Strategy for smart, sustainable and inclusive growth in the European Union. It also gained importance after the Global Financial Crisis in 2008 for reaching many European policy objectives in terms of the environment, climate change and energy issues;

➡ This trend justifies our decision to conduct our empirical analysis using data disaggregated at *province* level, since provinces represent the smallest level of governance for which exhaustive and complete data are available.

➡ The time period taken into consideration (2005-2015) is interesting since it reflects significant changes related to the energy sector in Italy.

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Empirical framework

- The development of public policy evaluation has benefited from the use of causal inference, which compares participants and non-participants in public policies → **propensity score matching** → takes into consideration endogeneity problems arising from selection bias (Fredriksson and Wollscheid, 2014; Sanchez-Braza and Pablo-Romero, 2014; Wang et al., 2019);
- This model requires the definition of a treatment indicator, which is traditionally a binary variable.
- However, our context is characterized by the presence of *two treatments*, corresponding to the two different energy policies analyzed, i.e. energy efficiency policy and renewable policy. These two policies can be applied by each province as mutually exclusive strategies or joint strategies to reach this goal.

→ a generalized propensity score matching approach with multiple treatments (Lechner, 2001, 2002)

Empirical framework

Four mutually exclusive groups of strategy (S) are thus defined:

- S_0 → the case of no treatment, describing the situation where no policies are implemented by the policymaker in the years 2005-2010;
- S_E and S_R → provinces only adopting energy efficiency policy and renewable energy policy in the period 2005-2010, respectively;
- $S_{E,R}$ → provinces where both these interventions are promoted in the time span 2005-2010;

- The main goal of our empirical analysis is to compare the effects on air pollution of these four mutually exclusive strategies S_0, S_E, S_R and $S_{E,R}$.
- In order to do that, the treatment indicator T_i is equal to 0, 1, 2 and 3 if S_0, S_E, S_R and $S_{E,R}$ respectively hold;

Empirical framework

- The treatment indicator T_i is employed for the estimation of the multinominal probit model, from which the propensity scores are obtained;

- They are then used in the estimation of the average treatment effects (using the matching technique following the nearest neighbor algorithm) in the following six pairwise comparisons:
  - S_E/S_0 → energy efficiency policy versus no treatment;
  - S_R/S_0 → renewable policy versus no treatment;
  - $S_{E,R}/S_0$ → energy efficiency and renewable policies versus no treatment;
  - $S_{E,R}/S_E$ → energy efficiency and renewable policies versus energy efficiency policy;
  - $S_{E,R}/S_R$ → energy efficiency and renewable policies versus renewable policy;
  - S_E/S_R → energy efficiency policy versus renewable policy;

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Data on air pollution

- Data related to the six gases employed in the empirical analysis disaggregated by activity according to the SNAP (Selected Nomenclature for Air Pollution) classification;
- The SNAP classification consists of 11 macro-sectors, which include all human activities relevant for atmospheric emissions, including agriculture, the industrial sector, and road, air, and sea transportation;
- They are available for all the 110 Italian provinces and the final selected observations refer to the year 2015;
- They are all measured in myriagram (Mg).
- They are organized to form six distinct panel datasets, one for each air pollutant, where the total number of cross-sections corresponds to the 110 Italian provinces, while the industry-dimension of each panel datasets corresponds to the SNAP items, which vary for each pollutant depending on data availability.

Table 1: Sustainable energy policies implemented either at *regional* or *local* level in Italy in the years 2005-2010.

	2005	2006	2007	2008	2009	2010
Energy efficiency policies						
Bolzano	no	no	no	no	no	yes
Emilia Romagna	no	no	yes	yes	yes	yes
Liguria	no	no	no	no	yes	yes
Lombardy	yes	yes	yes	yes	yes	yes
Marche	no	no	no	no	yes	yes
Piedmont	yes	yes	yes	yes	yes	yes
Trento	no	no	no	no	yes	yes
Umbria	no	no	no	no	no	yes
Valle d'Aosta	yes	yes	yes	yes	yes	no
Veneto	no	no	no	no	no	yes
Renewable energy policies						
Campania	yes	no	no	no	no	no
Emilia Romagna	yes	yes	yes	yes	yes	yes
Liguria	yes	yes	yes	yes	yes	yes
Lombardy	yes	yes	yes	yes	yes	yes
Marche	yes	yes	yes	yes	yes	yes
Tuscany	yes	no	yes	yes	yes	no
Trento	no	yes	yes	yes	yes	yes
Umbria	yes	no	yes	yes	yes	yes
Valle d'Aosta	yes	yes	yes	yes	yes	no
Veneto	yes	yes	yes	yes	yes	yes

Notes: "yes" ("no") indicates if the policy has been (has not been) implemented in that specific year. Author's elaboration on ISPRA data

Policy variables

Starting from Table 1, we compute the treatment indicator T_i, which identifies the status of each province among the four mutually exclusive strategies S_0, S_E, $S_{E,R}$ and S_R.

Explanatory variables

Some explanatory variables have been introduced in the multinominal probit estimation in order to control for the many factors that may influence local governments towards policy intervention

❖ These variables are:

- per capita GDP, population density and unemployment rate → referring to the main economic characteristics of each province and are retrieved from Eurostat (regional statistics);
- patents registered at the European Patent Office (EPO), measured in terms of number per million inhabitants → as a proxy of innovation;
- the decay rate of the loan facilities in percentage points → capturing the ability to attract financing for sustainable energy investments.

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Multinominal probit estimates

Table 2: Multinominal probit regression on estimating the propensity score at provincial level

	Energy Efficiency	Energy Efficiency and Renewable	Renewable energy
	Policy Adopters	Policy Adopters	Policy Adopters
Per capita GDP	0.2932***	0.7744***	0.1310*
	(0.0947)	(0.0710)	(0.0725)
Decay rate of loan facilities	-0.3011***	-0.2486***	0.0399
	(0.0526)	(0.0439)	(0.0394)
Patents	0.4616***	0.3666***	0.1426***
	(0.0498)	(0.0403)	(0.0423)
Population density	-1.0977***	-0.3484***	-0.0818
	(0.1024)	(0.0508)	(0.0498)
Unemployment rate	-0.9728***	-1.5764***	-1.8194***
	(0.0879)	(0.0827)	(0.0817)
Constant	-1.4632***	-1.1384***	-0.9782***
	(0.0838)	(0.0785)	(0.0727)
Observations	6,633	6,633	6,633

Notes: Standard errors are in parentheses. SNAP dummies are included but not presented.
A *(**)[***] indicates significance at the 10(5)[1] percentage level.

The estimated coefficients of the control variables show the expected sign;

With the sole exception of per capita GDP, the estimated coefficients are always higher when only energy efficiency policies are implemented;

Propensity scores assigned to each province are obtained from the results and are used to estimate the average treatment effects (ATT) in three distinct cases.

Sustainable energy policies In Italy

❖ We consider three cases of study, i.e. ***energy efficiency*** and ***renewable resource measures*** implemented in the years 2005-2010 on a

- ***local***
- ***regional***
- ***local and regional scale***

Sustainable energy policies on a local scale

We consider the impact of sustainable energy policies on air pollution when they are implemented on a *local scale*;

In fact, the literature reports many studies highlighting the importance of local governments for the development of sustainable energy sources, since they are key players in the adoption of new energy models or of already-known solutions (Economou, 2010; Michalena and Angeon, 2010 and Comodi et al, 2012);

The analysis is performed using the propensity scores derived from results reported by Table 2, and by using the set of dummy variables obtained from the following Table 3, which allows us to identify the six pairwise comparisons S_E/S_0, S_R/S_0, S_E/S_R, S_E/S_0, $S_{E,R}/S_0$, $S_{E,R}/S_R$ and $S_{E,R}/S_E$.

Policy variables

Table 3: Sustainable energy policies implemented at *local* level in Italy in the years 2005-2010.

	2005	2006	2007	2008	2009	2010
Energy efficiency policies						
Bolzano	no	no	no	no	no	yes
Lombardy	yes	yes	no	no	no	no
Piedmont (Turin)	yes	yes	yes	yes	yes	yes
Trento	no	no	no	no	yes	yes
Umbria	no	no	no	no	yes	no
Renewable energy policies						
Campania	yes	no	no	no	no	no
Trento	no	no	yes	yes	yes	yes
Liguria	no	no	no	no	yes	yes
Lombardy	yes	yes	no	no	no	no
Marche	no	no	no	no	yes	yes
Umbria (Corciano)	no	yes	yes	yes	yes	no

Notes: "yes" ("no") indicates if the policy has been (has not been) implemented in that specific year. Author's elaboration on ISPRA data

Starting from Table 2, we compute *three distinct dummies*:

- a dummy is obtained when the province located in each region adopts a energy efficiency policy (i.e. if the `yes' decision of the implementation of the policy is reported in the top part of Table 2) for more than one year in the period under investigation.
- A similar dummy is constructed for the case of renewable energy policies with reference to the bottom portion of Table 2;
- a dummy indicating when these two types of policies are jointly implemented is derived analogously.

Sustainable energy policies on a local scale

Table 4: The multiple treatment effects of renewable and energy efficiency policy applied at local level on air pollutants

	Global pollutants			Local pollutants		
Treated/control	CO2	CH4	N2O	NMVOCs	NOX	SOX
S_E/S_0	11.1773	3.1064	2.0709	0.4638	0.4305	4.8901
	(7.8906)	(3.7596)	(1.3502)	(0.4674)	(0.6050)	(3.766)
S_R/S_0	-0.5722***	-0.6009***	-0.6612***	-0.6621***	-0.6259***	-0.6611*
	(0.2074)	(0.1431)	(0.1298)	(0.1178)	(0.0802)	(0.3773)
S_E/S_R	-5.6147	0.3705	2.5439	0.5236	0.7939	6.1407
	(5.7439)	(1.2523)	(1.7353)	(0.4019)	(0.7727)	(4.8085)
$S_{E,R}/S_0$	1.3213	0.2832	0.0047	-0.6528***	-0.5064***	-0.5311***
	(0.7896)	(0.8865)	(0.2509)	(0.1372)	(0.0833)	(0.2057)
$S_{E,R}/S_E$	-0.3619**	0.1051	-0.2570*	-0.6983***	-0.5614***	-0.5705**
	(0.1688)	(0.2003)	(0.1323)	(0.0923)	(0.068)	(0.2914)
$S_{E,R}/S_R$	-0.3974*	-0.5072***	-0.3316***	-0.4775***	-0.2893**	-0.2271
	(0.2136)	(0.1220)	(0.0933)	(0.1124)	(0.1125)	(0.2249)

Notes: The estimated treatment effects are reported as a percentage of the untreated outcome means. Robust standard errors under parenthesis. A *, **, *** indicates significance at 10, 5, 1 per cent level.

Sustainable energy policies on a local scale

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Sustainable energy policies on a local scale

- Results show that energy efficiency policies alone are not effective. This occurs when the following strategies are considered: S_E/S_0 and S_E/S_R;

- Renewable policies are successful in terms of emission reduction when they are adopted alone (S_R/S_0), suggesting an average emission reduction equal to 65 per cent. This result holds independently of the types of pollutants taken into examination;

- When renewable and energy efficiency policies are jointly applied, the combinations of policies $S_{E,R}/S_0$ and $S_{E,R}/S_E$ work only in the case of the local pollutants, while estimations associated with the mix of policies $S_{E,R}/S_R$ are always negative, as expected, independently of the type of GHG emissions.

Sustainable energy policies on a local scale

With regard to these last three groups of strategies, it is worth noting that our results support the well-known **Jevons' paradox**, according to that **government policy** (or also technological progress) **increases the efficiency** with which a resource is used (reducing the amount necessary for any one use), but **the rate of consumption of that resource rises** due to increasing demand.

↑ Energy efficiency ↑ Consumption (rebound effect)

→ two policies are counter-productive (Alcott, 2005)

↓

In general, in the case of local interventions, **renewable policies** are the best solution with respect to climate goals, independently of the kind of emissions examined.

Sustainable energy policies on a regional scale and on a regional and local scale jointly

Regional policies are important determinants in terms of energy supply and demand, since energy targets are set at European level, but their implementation requires a strategy tailored by each Member State.

In the case of Italy, the policymaker sets up the National Action Plan and the National Energy Strategy, establishing energy guidelines;

These are then integrated by the Energy and Environmental Regional Plan and the Municipal Energy Plan, which are determined by *regions* and *municipalities*, respectively.

Table 5: Sustainable energy policies implemented at *regional* level in Italy in the years 2005-2010.

	2005	2006	2007	2008	2009	2010
Energy efficiency policies						
Lombardy	yes	yes	yes	yes	yes	yes
Marche	no	no	no	no	yes	yes
Valle d'Aosta	yes	yes	yes	yes	yes	no
Veneto	no	no	no	no	no	yes
Renewable energy policies						
Liguria	yes	no	no	yes	no	no
Lombardy	yes	yes	yes	yes	yes	yes
Marche	yes	yes	yes	yes	yes	yes
Tuscany	no	no	no	yes	yes	yes
Umbria	yes	yes	yes	no	no	yes
Valle d'Aosta	yes	yes	yes	yes	yes	no
Veneto	yes	yes	yes	yes	yes	yes

Table 6: Sustainable energy policies implemented at *regional* and local level in years 2005-2010.

	2005	2006	2007	2008	2009	2010
Energy efficiency policies						
Emilia Romagna	yes	yes	yes	yes	yes	yes
Liguria	yes	yes	yes	yes	yes	yes
Renewable energy policies						
Emilia Romagna	yes	yes	yes	yes	yes	yes
Liguria	no	no	yes	yes	no	no
Trento	no	no	no	no	no	yes
Tuscany	yes	yes	yes	yes	yes	no

Starting from Tables 5 and 6, *two additional groups* composed by *three dummy variables* are again computed following the same criteria described above.

Sustainable energy policies on a regional scale and on a regional and local scale jointly

The empirical analysis is carried out in a similar way to that described before;

Firstly, a set of dummy variables, derived from Table 5, indicating energy efficiency and renewable policies adopted on a regional scale in the years 2005-2010 are introduced;

To model energy policies adopted jointly on regional and local scale in the same time period, three additional dummy variables are built in the same way (see Table 6);

Note that Tables 5 and 6 show that regions adopting energy efficiency policies are precisely the same regions which adopted renewable energy policies;

Therefore, in this case, the analysis covers **only** the following combinations of strategies $\mathbf{S_R/S_0}$, $\mathbf{S_{E,R}/S_0}$ and $\mathbf{S_{E,R}/S_R}$.

As before, the empirical analysis is carried out by using the propensity scores derived from the findings shown in Table 2;

Sustainable energy policies on a regional scale

Table 7: The multiple treatment effects of renewable and energy efficiency policy applied at regional level on air pollutants

	Global pollutants			Local pollutants		
Treated/control	**CO2**	**CH4**	**N2O**	**NMVOCs**	**NOX**	**SOX**
S_R/S_0	-0.5426**	-0.5900***	-0.6264***	-0.6637***	-0.5856***	-0.5264**
	(0.2552)	(0.2492)	(0.1450)	(0.1567)	(0.0738)	(0.2076)
$S_{E,R}/S_0$	0.5001	-0.1505	0.1743	-0.5529***	-0.4756***	-0.5546***
	(0.6016)	(0.9050)	(0.2088)	(0.0985)	(0.0649)	(0.1924)
$S_{E,R}/S_R$	-0.2378*	-0.1131	-0.0179	-0.6233***	-0.2841***	-0.5546***
	(0.1262)	(0.1637)	(0.1227)	(0.1009)	(0.0874)	(0.2104)

Notes: The estimated treatment effects are reported as a percentage of the untreated outcome means. Robust standard errors under parenthesis. A *, **, *** indicates significance at 10, 5, 1 per cent level.

Only renewable policies are effective in reducing global gas emissions.

This result also holds in the case of the local pollutants.

When renewable and energy efficiency policies are jointly applied ($S_{E,R}/S_0$ and $S_{E,R}/S_R$), their impact is in general significant only in the case of the local pollutants → **Jevons' paradox still persistent** with the only exception of SOX

Sustainable energy policies on a regional and local scale jointly

Table 8: The multiple treatment effects of renewable and energy efficiency policy on air pollutants when applied at regional and local level jointly

	Global pollutants			Local pollutants		
Treated/control	CO2	CH4	N2O	NMVOCs	NOX	SOX
S_R/S_0	-0.4731**	-0.4252	-0.6518***	-0.4343	-0.5721***	-0.5554***
	(0.2312)	(0.3727)	(0.1518)	(0.3094)	(0.0838)	(0.2002)
$S_{E,R}/S_0$	-0.4977	-0.1946	-0.4881***	-0.6865***	-0.6055***	-0.4367*
	(0.3442)	(0.2105)	(0.1296)	(0.0928)	(0.0530)	(0.2537)
$S_{E,R}/S_R$	-0.5126***	-0.0467	-0.4396***	-0.6699***	-0.5970***	-0.2387
	(0.1528)	(0.3039)	(0.1206)	(0.1311)	(0.0603)	(0.2017)

Notes: The estimated treatment effects are reported as a percentage of the untreated outcome means. Robust standard errors under parenthesis. A *, **, *** indicates significance at 10, 5, 1 per cent level.

Previous results are generally confirmed also in this latter case → **Jevons' paradox is less evident** (it holds for N2O and SOX)
The performance of energy policies is indeed principally stronger in the case of local gases, while, when considering global pollutants, energy policies work only in the case of CO2 and N2O emissions;

Robustness checks: the tests for balancing hypothesis confirm the good performance of our matching procedure in all the cases analyzed.

Overview

- Introduction
- Aim of the paper
- A general overview of environmental quality and energy scenario in Italy
- Methodological framework
- Data
- Results
- Discussion and conclusions

Discussion

- Our findings demonstrate that, in general, renewable energy policies are the most effective in terms of climate goals. This holds independently of the kind of pollutant considered and the nature of the intervention (local, regional or both);
- Moreover, this is the only type of policy which ensures the expected pollution reduction when considering global air pollutants → Lehmann (2012) underlines that the negative externality generated by these kinds of gases may be corrected efficiently by a *single emission-based policy*, since the marginal damage produced by one pollution unit does not depend on the location of its emission and reception;
- This finding also justifies the impressive growth in the renewable energy sector in Italy during the last decade, which has more than doubled, rising from 7.9 per cent in 2005 to 18.2 per cent 2015;

Discussion

- Energy efficiency policies are a priority of the 2012 Energy Efficiency Directive, but their implementation encounters numerous obstacles given the presence of many barriers across all sectors, and they are mainly applied in towns in the North of Italy

→ This evidence may explain why energy efficiency policies alone are ineffective;

- The period analyzed covers the years of the Global Financial Crisis. As a consequence, it is likely that the counter-cyclical fiscal policies implemented to fight the crisis, together with the emission reductions due to slower economic activity, have reinforced the effect of energy policies on the environment;

- Local environmental policies are particularly desirable, and in this respect, the decentralization process of energy policy and planning procedures has been particularly successful in Italy;

Conclusions

This paper assesses the impact of renewable energy and energy efficiency policies on six different air pollutants, by using two novel datasets on greenhouse gases and sustainable energy policies adopted in Italy in the years 2005-2010;

The empirical analysis is performed using propensity score matching with multiple treatment;

We found that, among sustainable energy interventions, renewable policies are the most effective in terms of climate goals, while energy efficiency policies alone are ineffective, since they contribute to reducing air pollution only when adopted together with the renewable policies;

Moreover, the effectiveness of these interventions depend on the type of pollutant to be reduced

Conclusions

- In terms of policy perspective, it is worth noting that:

- Developing a more competitive and sustainable energy market is one of the most significant challenges for Italy's future (IEA, 2016);

- However, research and innovation in the energy sector is not at the required level, especially when compared to the other European countries, and despite the growing number of patent applications in energy efficiency and renewable energy technologies registered during recent years → warning for the Jevons' paradox

- Finally, the attractiveness of sustainable energy investments is also crucial for progress on the sustainable energy agenda. Creditworthy utilities are the central player in the development of energy access, renewable energy and energy efficiency. Uncertainties affecting financial markets often lead to higher perceived risks, and therefore to more stringent investment criteria and a higher hurdle rate.