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by

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Abstract

Despite biogas is considered a renewable source of energy, the social acceptability of biogas plants is controversial due to resistance from local communities who are afraid of potential local negative externalities. This paper aim at investigating this claim using evidence from the housing market by means of a diff-in-diff model. Indeed, if households evaluate the presence of biogas plant such as a disamenity, this should be incorporated in the housing values. To this purpose I use data on the housing market of Piedmont provinces where 167 biogas plants have been opened between 2006 and 2015. Results show no significant impact of the opening of a biogas plant on the housing values.

1. Introduction

Italy is one of the countries with larger energy production though biogas plants in the world. In 2016 Italy accounts for 1,224 biogas plants and 947 MW installed power with an electricity generation capacity of 6,057 GWh (equal to the 15% of the total energy produced by renewable in Italy; GSE, 2016). The number of biogas plants has been increasing in the last years (e.g. the number of biogas plants in 2010 was 313 according to GSE, 2010) and this is also underlined by the fact that substantial investments were made for an amount of 4.5 billion euro in the last five

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years. It has been estimated that the number of biogas plants should be double before 2030 (Althesys, 2015).

Despite the positive effect on local areas due to reduction of pollution and emission of CO2, the social acceptability of biogas plants is controversial due to resistance from local communities who are afraid of potential local negative externalities including smell, heavy traffic and congestion, noise and visual disamenities. Then, one of the biggest challenges for policy makers and private actors in siting new biogas plants is the resistance of local communities. To evaluate these claims this paper uses evidence from the housing market. Indeed the price of real estate incorporates both intrinsic quantitative and qualitative attributes and 'external' attributes. The external attributes arise from the location, and they are referred to the amenities of the reference areas, including the surrounding housing characteristics. It follows that if households evaluate the presence of a biogas plants such as a disamenity, this should be incorporated in the housing values, producing a decreasing in the price of housing in the nearby of plants after the opening of a biogas plant.

This paper tests this eventuality using 167 biogas plants opening in Piedmont between 2006 and 2015 by means of a diff-in-diff model. It also differentiates between authorization date and opening date. Advantages of a diff-in-diff model are summarized in Hallstrom and Smith (2005) and Modica et al. (2016): first, it accounts for possible fluctuations of the market, second, it isolates the effects of new information brought by the opening of a biogas plant.

The results show that the average level of the housing prices in the area where biogas plants localize is not significant different from the other parts of the region, unless the plant owns a CHP (combined heat and power) unit. In this case the housing values of a particular kind of residential unit (low-quality housing) is 1% lower in a 2km radius from the biogas plant than in the other part of the region. To the best of my knowledge this is the first paper aiming at evaluating the impact of the opening of a biogas plant on housing values. Even though, it should be noted that dozens of studies have used residential housing market data to estimate the impact of locally undesirable facilities and or environmental quality on housing prices (Davis, 2011). While most of the papers focuses on evaluating the impact of hazardous waste sites (Gamper-Rabindran and Timmins, 2013; Gayer et al., 2000; Greenstone and Gallagher, 2008; Ham et al., 2013; Kiel and Williams, 2007; McCluskey and Rausser, 2003), few others focus on specific type of plants, for instance hazardous industrial plants (Grislain-Letrémy and Katossky, 2014); nuclear power plants (Ando, 2015); power plants (Davis, 2011); toxic plants (Currie at al., 2013; Sanders, 2011); waste incinerators (Kiel & McClain, 1995) and wind turbines (Lang et al., 2014)[1]. The paper is organised as follows: Section 2 describes the general framework, the main characteristics of biogas plants, the subsidies and potential positive and negative externalities, Section 3 describes data and method, Section 4 provides the results of the analysis and in Section 5 some policy implications are analysed. Finally, Section 6 concludes.

2. Biogas Plants: Characteristics, Subsidies and Externalities

The production of biogas is a complex and variegated activity that derive from the exploitation of waste from livestock (e.g. manure), food production (e.g. fruit, vegetable and food scraps), and from industrial and municipal wastewater treatment plants (e.g. sewage sludge). Biogas is produced by anaerobic fermentation of organic substances in special fermenters and it is a mixture consisting mainly of methane and carbon dioxide. The organic materials is converted into biogas by means of a complex biological process that is different according to several variables (e.g. kind of waste, temperature and so on, for a review see Brown et al., 2013; Møller and Martinsen, 2013 and Poeschl et al., 2012). The transformation of biogas into energy can occur by direct combustion with production of heat only or by combustion in co-generators producing in this way both electricity and heat. Biogas could also be purified in methane, becoming in this way bio-methane and it can be used as fuel for other vehicles.

[1] Readers can consult Farber (1998) for a review of the literature of older studies.

Given these premises biogas plants benefit from a range of environmental advantages that can be summarised in the following points:

- They have no risks of extraction and transport and low risk of severe accidents (Burgherr et al., 2014),
- small local plants do not have high production and transport costs (Raven and Gregersen, 2007),
- lower (or equal) CO2 emissions than the amount absorbed by the plants for growth with zero or positive effect (Boldrin et al., 2016),
- re-use of agricultural waste and production of high-quality fertilizer (Robinson et al., 2001),
- "*Applications of the spent feedstock or digestate from biogas production as fertilizer minimizes the use of energy intensive chemical fertilizers to further alleviate GHG emissions*" (p.168, Poeschl et al., 2012).

Because of all these advantages biogas plants can play an important contribution in producing energy from renewable sources and in the disposal of organic waste. For these reasons, in several countries (especially within European Union Member States) energy production through biogas has been encouraged. For instance, the 2009/28/CE directive set the overall share of energy from renewable sources to be achieved by 2020 for any EU Member States (for Italy the share is equal to 17% of the gross final consumption of energy and 10% as share of renewable energy for all mode of transport, D.lgs. 28/2011). In line with the EU directive, Italy has then introduced a number of subsidies aimed at favouring the energy production through renewable resources, in particular Italy developed the so-called *'Certificati Verdi'* (from now on CV). CVs are negotiable securities issued by GSE (the private company that is in charge of the management of the Italian energy services) in proportion to the energy produced by a plant powered by renewable sources. The incentive mechanism is based on the obligation of producers of energy through non-renewable sources to feed every year a minimum quota of electricity produced by renewable sources. ‘Non-renewable producers’ then buy CVs from ‘renewable producers’. The duration of the incentives is twelve years and it can be postponed of four years in the case of biogas plants. This favourable framework are without any doubt able to promote the broad adoption of biogas technology.

However, the social acceptability of biogas plants, among other renewable resources, is maybe at the lowest level due to resistance from local communities who are afraid of potential local negative externalities (ARPAT, 2015). The perceived environmental disadvantages can be summarised in the following points:

- Intensification of soil erosion problems and nutrient loss by the harvesting of crop residues (Abbasi and Abbasi, 2000; Magnani, 2012)
- air and water pollution due to possible emissions of particulates and oxides (Abbasi and Abbasi, 2000)
- biomass burning for the production of energy may be associated with the combustion of waste (ARPAT, 2015; Skøtt, 2006; Soland et al., 2013; Upham and Shackley, 2006)
- oversizing of the plants with respect to the availability of the raw material that leads to an increase of heavy vehicle traffic (ARPAT, 2015; ; Upham and Shackley, 2006)
- smell (Skøtt, 2006; Soland et al.,2013)
- distributive justice (Gross, 2007; Magnani, 2012) in the case of large centralised biogas plants centralized biogas plant that would accrue only to a few powerful actors.
- reduced property values or loss of customers (Skøtt, 2006; Soland et al., 2013)
- visual disamenities because. plants could spoil the natural landscape (Soland et al., 2013)

As denoted above, several studies have provided evidence of limitations in the social acceptability of biogas as energy from renewable sources. It is interesting to notice that only very few papers have directly investigated the possibility of financial losses of households next to biogas plants (through survey analysis). For instance a survey provided by Soland et al. (2013) reports low score (1.91 over 6) regarding the possibility to get a financial loss (e.g. reduced property values) due to the proximity of biogas plants. As denoted by the authors, the survey has been made among Swiss citizens living near biogas plants where no strong protests prevail. To the best of my knowledge there are no papers quantitatively analyzing the impact of the opening of a biogas plant on the housing values. To evaluate these claims this paper uses evidence from the housing market. The next section describes the data and the method used for the analysis.

3. Biogas plants localities, housing market data, and evaluation model

The data on the localization of the biogas plants in Piedmont are provided by the Regional Agency for Environmental Protection of Piedmont (ARPA – Piemonte). The database provides information over 167 biogas plants and their localization. The available information includes address, installed power, presence of CHP (combined heat and power) unit; authorization date and effective opening date. Descriptive statistics are provided in Table 1.

<Table 1 about here>

The housing values are provided by the 'Italian Tax and Revenue Service' (Agenzia delle Entrate). This database makes available average prices of houses for specific sub-municipal areas derived from the actual transactions that take place in the housing market. The data are grouped by type and current quality status of the house at sub-municipal level. Even though, there is the possibility to select different types of building units, for the aim of this work, I focus only on residential buildings, these can be classified as 'high-quality' residential unit, that shows good general characteristics and value; 'low-quality' residential unit, that shows low general characteristics and value and 'villa' that is single-family residential unit with superior construction characteristics. The spatial scale is very detailed and it is possible to focus on sub-municipal areas, namely homogeneous segments of the local real estate market that own uniform economic and socio-environmental conditions. The data cover the period 2006 - 2015 and are semi-annual. Table 2 provides main distributional statistics for sub-municipal areas of Piedmont in comparison to the overall number of municipalities of Piedmont.

<Table 2 about here>

The main empirical challenge in such a study is constructing an appropriate treated group (e.g. areas with an opening of a biogas plant at a given distance) and a suitable counterfactual for the locations where biogas plants were opened. The adopted strategies is then the following: first, the analysis focuses on cross-sectional comparisons between locations with and without biogas plant. With the aim of selecting appropriate treated areas I focus on sub-municipal areas that have a biogas plant within a distance of 2 km from their centroid. This distance has been considered because odour nuisances (here used as a proxy for noise due to biogas plant) can reach 2 km (see Skøtt, 2006). However, we do not consider rural areas because typically all the surrounding area of a municipality is considered as a single homogenous housing market area and this can lead to bias our analysis. Finally, we consider as control group all the other homogenous market areas that have no biogas plants nearby. Figure 1 shows a map of treated and control areas.

<Figure 1 about here>

Table 3 shows descriptive statistics of the housing values in reference to the treated and non-treated. Moreover, I also show detail for type of housing (e.g. ‘high-quality’ housing, ‘low-quality’ housing and ‘villa’).

<Table 3 about here>

To evaluate the market response to the opening of biogas plant we use a standard diff-in-diff model as follow:

$$\log\left(\mathrm{Price}_{i,j,t}\right) = \alpha_{i,j} + \beta_1 D_j + \beta_2 D_j * \mathrm{Post}_t + \mathrm{yeardummy} + \gamma X'_{j,t} + u_{i,j,t} \qquad (1)$$

where the dependent variable is the log of the average price of the housing values, *i*, in the sub-municipal area, j, at time t. D is a dummy variable equal to 1 if the observation is in the treatment groups (i.e. in area next to a biogas plant) or 0 otherwise, $Post$ is a dummy that assumes value 1 if the treatment occurs and 0 otherwise. I also add a set dummies able to capture specific biogas plants characteristics, $X'_{j,t}$ such as *Size* (dummy variable assuming value 1 if the installed power is higher than 1Mw), *CHP* (dummy variable assuming value 1 if the plant owns a combined heat and power unit) and *Multiple Plants* (dummy variable assuming value 1 if there are more than one plant). We use a time fixed effect model. Following Bertrand et al. (2004), to do not incur in serial correlation, we run block bootstrap with 500 replications by keeping all the observations that belong to the same province (Efron and Tibshirani, 1994).

This model is able to control for regional-specific multiple shocks. However, the treated and the control groups must have similar trends in the year before the opening of biogas plants for identifying the causal effect of the biogas plant. To examine potential pre-existing trends we run the following model:

$$\log(Price_{i,j,t}) = \alpha_{i,j} + \sum_{t<2012} \tau_t D_j T_t + u_{i,j,t} \qquad (2)$$

where τ_t are the coefficients on time dummies T_t. We then test the jointly significance of the estimated τ_t coefficients before the treatment. If the test does not reject the H_0 we can affirm that the two samples satisfy the common trend assumption. Tab. 4 provide evidence for the acceptability of the common trend assumption.

<Table 4 about here>

4. Results

In this section, we present the results of the analysis. We run several models that take into consideration the differences that in some cases arise between the date of the authorization to build a biogas plant (Table 5) and the effective date of the opening (Table 6). We also differentiate for type of housing to control for the hypothesis that ‘prestigious’ house values might be more affected than non-prestigious houses. In Tab. 5 we report the results in relation to the impact of the authorization of opening a biogas plant on the housing market. In any case the results are not significant. Similar results are obtained when looking at the impact of the opening of a plant on the housing market, with the only exception of a slightly negative and significant effect (lower than 1%) of biogas plants that own a combine heat and power unit on low quality houses. However, generally I show the non significant impact on housing market of the presence of a biogas plant in the nearby of urbanized areas.

<Table 5 about here>

<Table 6 about here>

5. Policy Implications

Even though this study does not provide evidence of a significant impact of opening of biogas plant on the housing market, it is necessary to stress the fact that previous studies on social acceptability from local communities have underlined some constraints that may limit the acceptability of biogas plants. In particular three main characteristics seem to be important: oversizing of the plants; odour nuisances and lack of information from institutions. The absence of significant adverse impacts on property values certainly plays an important role in avoiding the need to allocate incentives to households in relation to the potential reduced property values. However, it might be appropriate to implement a system for incentivising the social acceptability of biogas plants from households through better institutional communication or throughout the provision of discounted price for energy and heat (and biomethane) through a system of vouchers.

6. Conclusion

The production of biogas is a complex and variegated activity, however despite the possible environmental positive effect on local areas, the social acceptability of biogas plants is controversial due to resistance from local communities. If households evaluate the presence of a biogas plants such as a disamenity, policy makers and private actors should face the resistance of local communities, also because a new biogas plant could lead to a reduction in the price of housing in the nearby of plants. However, analyzing 167 biogas plants opening in Piedmont between 2006 and 2015 by means of a diff-in-diff model, I have provided no evidence of such a claim, namely the opening of biogas plants do not produce any significant negative (nor positive) effect on the housing values of different kind of residential units. Further analysis need to confirm this evidence.

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Table 1 – Descriptive Statistics on biogas plants

Biogas plant characteristics	**No. observations**	**Average value**	**Standard deviation**	**Min**	**Max**
Installed power (KW)	167	700.61	711.48	50	8000
CHP unit	84	-	-	-	-
Authorization date	157	2010	2.2	1995	2014
Opening date	149	2011	2.2	1995	2014

Table 2 – Distribution of sub-municipal areas

Biogas plant characteristics	**No. observations**
Municipalities	1,210
Sub-municipal areas	3,854
Central sub-municipal areas	1,315
Semi-central sub-municipal areas	225
Sub-urban sub-municipal areas g date	1,434
Rural sub-municipal areas g date	1,749

Table 3- Descriptive statistics

Type of house	No. Observations	Average log(price)	Standard deviation	Min	Max
		All sample			
All types	75,193	6.95	.32	5.70	8.43
‘High-quality’ house	33,339	6.93	.34	5.77	8.43
‘Low-quality’ house	18,776	6.84	.30	5.70	8.16
Villa	23,078	7.05	.26	6.21	8.27
		Treated Area			
All types	10,065	6.95	.26	5.76	7.61
‘High-quality’ house	4,444	6.93	.29	5.77	7.61
‘Low-quality’ house	2,550	6.87	.24	6.07	7.50
Villa	3,071	7.03	.21	6.21	7.60
		Control Area			
All types	65,128	6.95	.32	5.70	8.42
‘High-quality’ house	28,895	6.93	.34	5.81	8.43
‘Low-quality’ house	16,226	6.83	.31	5.70	8.16
Villa	20,007	7.05	.26	6.21	8.23

Table 4 - Pre-treatment common test

Sample	Authorization date		Opening Date	
	F test	p-value	F test	p-value
All observations	0.97	0.51	1.64	0.32
High-quality housing	2.43	0.20	2.33	0.22
Low-quality housing	7.53	0.06	1.21	0.44
Villa	2.30	0.22	3.54	0.12

Table 5 - Diff-in-diff by type of buildings (date of authorization)

Independent variable	log of the average price							
	All residential units		‘High-quality houses’		‘Low-quality houses’		Villas	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	6.909***	6.909***	6.876***	6.876***	6.805***	6.806***	7.040***	7.040***
	(0.0503)	(0.0504)	(0.0823)	(0.0823)	(0.0465)	(0.0461)	(0.0485)	(0.0486)
Interaction (β2)	0.00323	0.00204	0.000938	-0.000300	0.00342	0.00474	0.00678	0.00364
	(0.00997)	(0.00699)	(0.0113)	(0.0102)	(0.0105)	(0.00407)	(0.0110)	(0.00559)
Size		0.00223		0.00235		-0.0291		0.0294
		(0.0446)		(0.0361)		(0.0737)		(0.0431)
CHP		-0.00844		-0.00657		-0.00917		-0.0102
		(0.00673)		(0.00973)		(0.00563)		(0.0141)
Multiple plants		0.0354		0.0315		0.0506		0.0232
		(0.0295)		(0.0163)		(0.0569)		(0.0288)
Time dummies	YES	YES	YES	YES	YES	YES	YES	YES
r2	0.116	0.118	0.118	0.118	0.172	0.174	0.0992	0.102
N	75193	75193	33339	33339	18776	18776	23078	23078

Table 6 - Diff-in-diff by type of buildings (opening date)

Independent variable	log of the average price							
	All residential units		'High-quality houses'		'Low-quality houses'		Villas	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Constant	6.909***	6.909***	6.876***	6.876***	6.805***	6.806***	7.040***	7.040***
	(0.0503)	(0.0504)	(0.0823)	(0.0823)	(0.0465)	(0.0461)	(0.0485)	(0.0486)
Interaction (β2)	0.00329	0.00205	0.00131	0.000907	0.00423	0.00471	0.00544	0.00150
	(0.00804)	(0.00419)	(0.00871)	(0.00579)	(0.0126)	(0.00411)	(0.00813)	(0.00511)
Size		0.00520		0.0101		-0.0225		0.0226
		(0.0397)		(0.0322)		(0.0736)		(0.0328)
CHP		-0.00931		-0.0102		-0.00978**		-0.00738
		(0.00571)		(0.00871)		(0.00408)		(0.0141)
Multiple plants		0.0323		0.0262		0.0508		0.0220
		(0.0301)		(0.0180)		(0.0599)		(0.0263)
Time dummies	YES	YES	YES	YES	YES	YES	YES	YES
r2	0.116	0.118	0.118	0.118	0.172	0.174	0.0991	0.101
N	75193	75193	33339	33339	18776	18776	23078	23078

* p<0.1, ** p<0.05, *** p<0.01 (block-bootstrapped standard errors in parentheses)

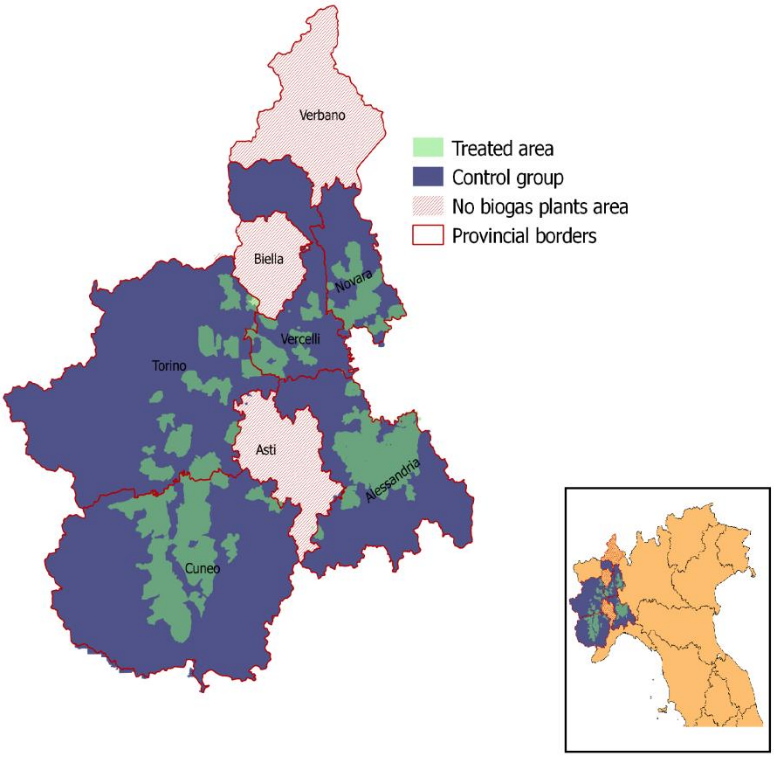

Figure 1 Study area