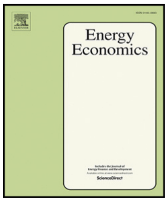
Energy Economics 125 (2023) 106844

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco



Unburdening regulation: The impact of regulatory simplification on photovoltaic adoption in Italy[☆]

Federica Daniele[a], Alessandra Pasquini[a], Stefano Clò[b,*], Enza Maltese[a]

[a] Bank of Italy, ARET-RM, Directorate General for Economics, Statistics and Research, ARET-CZ, Italy
[b] University of Florence, Department of Economics, Italy

ARTICLE INFO

JEL classification:
H23
K32
L51
Q42

Keywords:
Photovoltaic investment
Regulatory simplification
Regions

ABSTRACT

This paper measures the impact of a series of reforms enacted by a subset of Italian regions during 2009–2013 that dramatically simplified the authorisation procedure for investment into mid-sized to large sized photovoltaic plants, i.e. plants with capacity installed between 20 and 200 kW. We rely on georeferenced administrative data on nearly the universe of photovoltaic plants built in Italy, and employ a stacked border diff-in-diff around the time of the regional reforms and municipalities located close to the border of regions that implemented them. We find that simplification reforms increased by 29 percentage points the capacity installed in medium-to-large plants, which resulted into 12 extra MW installed per quarter, about 10% of average quarterly installations for the same category of plants during 2009–2013.

1. Introduction

Renewable plants permitting process creates non-negligible administrative barriers, and it is often invoked as one of the main factors delaying the deployment or even preventing projects from being realised (European Commission, 2020).

A good knowledge on the policy tools available to foster the installation of renewable energy sources is fundamental for multiple reasons. First, the European Union (EU) ambition to become climate neutral by 2050 (European Climate Law, Regulation EU/2021/1119) poses an unprecedented challenge. The European Union committed to cut greenhouse emissions by 40% by 2030 compared to 1990 levels.[1] Electric renewable energy sources (RES-E), and photovoltaic (PV) technology in particular, are expected to bring the major contribution to achieve these targets (according to the 2020 National Energy and Climate Plan or NECP). In Italy, the RES-E share will have to increase from the 35% share registered in 2019 up to 55% in 2030. According to conservative estimates from NECP, to reach this goal, the total power of PV installation has to grow by 30 GW between 2020 and 2030, while during the period 2015–2020 only 0.5 GW/year were installed on average. Financial incentives alone seem not to be sufficient to reach this goal. Indeed, although the average levelised cost of energy of utility-scale solar photovoltaic fell 82% between 2010 and 2019 (IRENA, 2020), photovoltaic growth has been sluggish in those years, in spite of the available financial subsidies. Besides NECP goals, RES installation could increase the energy independence from imported fossil fuels and contribute to lower energy costs for the investors. Moreover, enhancing the role of consumers in the energy market by empowering them to generate their own electricity is essential to create a resilient energy system. This is especially relevant when facing sharp spikes in energy prices and price fluctuations as those we are witnessing today.

Financial incentives to RES development - on which the relevant literature has so far predominantly focused (Scerrato, 2015; Antonelli and Desideri, 2014; Monarca et al., 2018) - are not the only type of policies that can stimulate investments. The propensity to undertake RES investments depends also on the degree of legal uncertainty and the magnitude of direct and indirect costs associated with authorisation procedures. More uncertainty increases the option “wait and see” value of undertaking an investment, thus reducing the propensity to invest (Bloom et al., 2007). Burdensome authorisation procedures entail indirect costs (other than direct administration fees), such as those related to the time necessary to acquire the relevant information,

---

[☆] The views expressed in this research are exclusively the authors’, and they do not reflect the ones of Banca d’Italia. The collaboration of *Gestore dei servizi energetici S.p.A*, and in particular the assistance provided by Paolo Liberatore with the data, is gratefully acknowledged.

* Corresponding author.
E-mail addresses: federica.daniele@bancaditalia.it (F. Daniele), stefano.clo@unifi.it (S. Clò).

[1] The recent Climate Package *Fit for 55: delivering the EU’s 2030 Climate Target on the way to climate neutrality* adopted on 2021 July has enhanced these targets. The document sets the reduction of net emission by at least 55% by 2030. Further, it proposes to increase the RES 2030 target from the current 32% to 40%.

https://doi.org/10.1016/j.eneco.2023.106844
Received 27 October 2022; Received in revised form 20 June 2023; Accepted 26 June 2023

process it and return it to the public administration, that can constitute a significant entry barrier, particularly for small (self-)entrepreneurs who do not possess the relevant legal skills.[2] In this paper, we assess the impact of a set of simplification reforms implemented by a few regions during the years of the PV boom in Italy (2009/2013), whose aim was to streamline the authorisation procedure to build medium-sized PV plants (20–200 kW). While one would reasonably expect such reforms to be successful at promoting RES development, this is the first paper to our knowledge showing that this is the case and that the ensuing investments are truly additional in a rigorous empirical setting. In so doing, we are also able to shed light on the sources of heterogeneous spatial diffusion of PV investment across regions during our period of focus.

Since 2003, according to D.Lgs.387/2003, the construction of PV plants with capacity exceeding the 20 kW threshold had to be explicitly authorised by local administrations through a lengthy and burdensome authorisation procedure called *Autorizzazione Unica* (AU). Starting from 2008, some regions introduced exemptions from AU for medium-sized plants. Our exercise consists of evaluating the effectiveness of the introduction of AU exemptions at spurring investment into medium-sized PV plants (2009/2013). This size of plants is extremely relevant in the Italian context. It represents roughly 30% of PV capacity installed in Italy during 2009/2013. Furthermore, it is an alternative to utility-scale PV systems which must necessarily be installed on the ground with non-negligible environmental impact in terms of land use and agricultural land conversion.

We rely on administrative microdata covering roughly the universe of renewable energy plants built in Italy. The data are provided by the *Gestore dei Servizi Energetici* (GSE), a publicly owned company that manages the provision of subsidies to renewable energy producers. We focus on newly PV capacity installed in plants with capacity between 20 and 200 kW. Our stacked diff-in-diff makes use of both the time and space discontinuity available in our setting in order to eschew as many confounding factors as possible. To deal with the different timing of policy implementation, we cast our border diff-in-diff exercise into a stacked diff-in-diff as Autor et al. (2006) but limiting ourselves to municipalities located close to regional borders. Next, we check for the presence of plants sorting across regions excluding municipalities close enough to the border to be potentially affected. We check for the presence of displacement across different power levels both with a placebo test on small-sized plants and studying how bunching changes after the reform. We inspect whether the effect is heterogeneous along a few characteristics that we deem meaningful from a policy point of view. Finally, to further lend credibility to our results, we provide validation tests for the main assumptions of our identification strategy.

Our estimates indicate that the simplification reforms increased, on average, by almost 29 percentage points the capacity installed during the first nine months after the reform in medium-sized plants at the quarter/municipality level, which resulted into 12 extra MW installed per quarter, about 10% of average quarterly installations for the same category of plants during 2009–2013. Importantly, this effect is driven neither by the sorting of plants across regional borders, nor by the displacement of investment from small- to medium-sized plants.[3] The estimated effect does not differ significantly between municipalities characterised by more or less solar radiation, thus suggesting that, while being effective, simplification reforms were not particularly efficient at stimulating PV energy deployment in parts of the country were the yield is the highest. The estimated effect does not differ either between municipalities characterised by more or less public sector efficiency, thus suggesting that simplification reforms neither contributed to widening the investment gap between areas where public administration is more efficient and those where it is less so, nor they helped towards closing this gap, by favouring disproportionately traditionally inefficient areas that might have needed regulatory simplification the most.

Our work contributes to the existing literature both in terms of the methods used and in terms of the findings we reach. In terms of the methods, this is the first work assessing the causal impact of regulatory simplification measures on PV investments by relying on rigorous econometric techniques, which allow eschewing potential biases stemming from endogeneity in both policy adoption and its timing. In terms of the findings, while regulatory simplification is intuitively expected to fasten PV adoption, ours is the first paper - to the best of our knowledge – to confirm this theoretical expectation empirically. Further, our work shows that the increased PV adoption observed in the regions affected by the reforms does not stem from displacement across regions but it is rather the result of additional investment. Besides empirically assessing the impact of regulatory simplification on PV adoption, we discuss its efficiency within a Cost-Benefit Analysis (CBA) framework. According to the relevant literature, renewables installations' major external costs (loss of biodiversity, visual and noise disamenities, land grabbing, property value depreciation) are mainly associated with utility-scale plants. Being our research focused on small to medium-sized plants, we are able to conclude that the benefits stemming from regulatory simplification and ensuing faster PV adoption likely outweigh the related social costs. This conclusion supports the recent decision by the European Commission to declare renewable energy projects "of overriding public interest and serving public health and safety". Finally, our findings can have relevant policy implications for other countries where the length and complexity of the administrative procedures represent a major obstacle to PV adoption as well. In particular, our findings help evaluating the recent permitting simplification measures proposed by the European Commission within the context of the REPowerEU package, as properly addressed in the "discussions and policy implications" section of the paper.

Literature review This paper is mainly related to two strands of literature. The first one is the literature on the impact evaluation of regulatory simplification on economic activity, particularly on investment. A few studies have analysed empirically the impact of public sector inefficiency and burdensome regulation on economic performance (Helm, 2006; Accetturo et al., 2017; Giacomelli and Menon, 2017; Fadic et al., 2019; Giordano et al., 2020), often finding that raising public sector efficiency can yield large economic benefits. Within this literature a subset has specifically focused on the interplay between the legislative framework and investment in renewable energies (Giaccaria and Dalmazzone, 2012; Karteris and Papadopoulos, 2013; Germeshausen, 2018; Wanga et al., 2019). To the best of our knowledge, we are the first to evaluate the impact of the former on the latter by means of a counterfactual approach.

The second strand of literature this paper relates to is the one analysing the spatial diffusion of PV plants. This literature has been mostly concerned with the measurement of the role played by socio-economic and environmental factors in shaping PV investment, such as peer-effects (Bollinger and Gillingham (2012) and Schaffer and Brun (2015)), criminality (Caneppele et al., 2013), solar radiation (Schaffer and Brun (2015) and Monarca et al. (2018)), economic development, among many other factors (Balta-Ozkan et al., 2015; Schaffer and Brun, 2015; Copiello and Grillenzoni, 2017; Dharshing, 2017). The paper most closely related to ours is Germeshausen (2018), who analyses the (distortionary) impact of plant size-specific discontinuities in the subsidy schedule on PV investment across German municipalities. Unlike

---

[2] Both the Renewable Energy Directive (RED) and the European Commission 5th National Renewable Energy progress report outline the importance in the Italian case of reducing administrative barriers for PV investment, in particular the simplification of the single authorisation procedure. The reduction of administrative barriers are among the key enablers to boost PV energy deployment according to the NECP and the National Recovery and Resilience Plan (NRRP).

[3] The removal of administrative barriers may reduce the potential bunching it caused.

Germeshausen (2018), we focus on the impact on PV investment of plant size-specific discontinuities in the regulatory burden. Specifically, we contribute to this literature by highlighting the role of regulatory simplification in driving geographical differences in PV plants diffusion across Italian regions during the 2009–2013 PV investment boom.

The rest of the paper proceeds as follows: Section 2 describes the regional regulatory simplification reforms evaluated in this work; Sections 3 and 4 present the data that we use and the empirical strategy; Sections 5 and 6 show the results and discuss the plausibility of the identifying assumptions; Section 7 highlights some policy considerations in terms of efficiency of the policy; Section 8 concludes.

2. Policy context

In 2003, national legislation (D.Lgs. 387/2003) established two alternative authorisation procedures for the installation of PV plants. Plants with a capacity below the 20 kW threshold could follow a simpler and faster authorisation procedure, in 2011 renamed *Procedura Abilitativa Semplificata* (Simplified Authorisation Procedure, or PAS). It allowed to install plants after the submission of a communication signed by an engineer and an architect/surveyor to the local municipal authority. This procedure followed the silence-consent mechanism: if no feedback was received from the competent Public Administration within 30 days from the submission date, an implicit authorisation to carry out the works was granted.

Plants with a capacity above the 20 kW threshold had instead to follow a more burdensome and lengthy procedure, the so-called *Autorizzazione Unica* (Single Authorisation, or AU). This represented essentially a bundle of authorisations that needed to be obtained individually (e.g., the building permit, the authorisation for the construction and operation of the power line, the landscape clearance, etc.) and required the involvement of a plurality of local, regional and national stakeholders. Furthermore, the indicated authorisations needed to be accompanied by several environmental and landscape impact assessments, drawn up by a variety of technical professionals.[4] The volume of the documentation required translated into long waits before obtaining the authorisation, e.g. Fig. A.1 represents the time elapsed before obtaining the AU in the region of Puglia.

Aside from the high regulatory burden and coordination costs, the AU also entailed a high degree of regulatory uncertainty. In spite of D.Lgs. 387/2003 containing the provision of upcoming national guidelines, these were published only in 2010. Hence, between 2003 and 2010 a few regions started acting independently and simplifying the authorisation procedure for the installation of medium-sized PV plants within their boundaries.[5] In 2009, the European Directive 2009/28/EU established, among other things, that the burden imposed by the authorisation procedure had to be proportional to plant size. As a consequence, the D.Lgs. 28/2011, issued on March 3, 2011, authorised regions to exempt plants up to 1 MW from filing the "Autorizzazione Unica".[6] As a result, during 2009–2013, five regions (Abruzzo, Basilicata, Calabria, Friuli Venezia Giulia and Lazio) and the autonomous province of Trento adopted the generalised exemption up to 1 MW, and six more introduced partial exemptions, i.e., Emilia-Romagna, Lombardia, Sardegna, Sicilia, Umbria and Veneto (Fig. 1).[7]

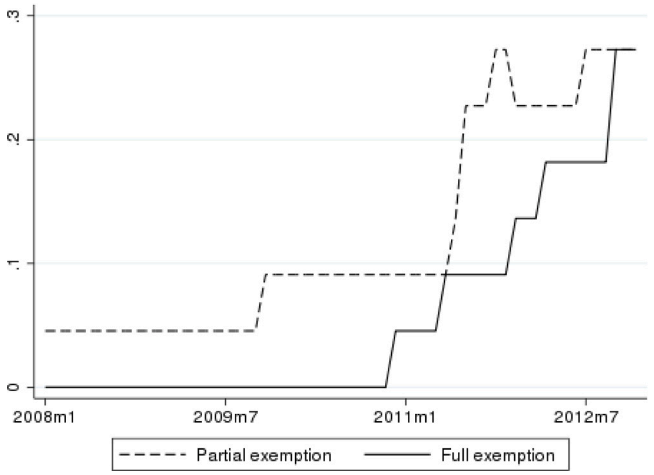


Fig. 1. Implementation of partial/full exemption from "Autorizzazione Unica" (% of implementing regions).
Source: Authors' elaborations.

3. Data

The main dataset we employ for this analysis is provided by the *Gestore dei Servizi Energetici S.p.A.* (GSE), a publicly owned company managing the provision of subsidies to renewable energy producers. The GSE is the prime source of administrative data on Italian renewable energy plants requesting access to state subsidies. We focus on the period between 2009 and 2013, during which the Italian feed-in premium mechanism, the so-called *Conto Energia*, was in place and 90% of total PV capacity put up between 2005 and 2020 was installed (see also Fig. B.2).[8] Within the PV/electric segment, our data source covers nearly the universe of Italian renewable energy plants: the plants included in our dataset amount to 92.4% of cumulative capacity installed in Italy between 2009 and 2013 (Terna, 2020).

For each PV plant producing electrical energy we have information on: (1) the municipality where it is located, (2) the month when it went into operation (and thus it was connected to the grid), (3) the capacity installed, (4) whether the owner of the plant is a natural person or a legal entity, (5) the incentive scheme, (6) whether the plant is built on or off the ground. In our analysis, we aggregate PV

---

[4] To name a few: seismic declaration; urban and territorial framework and verification of coherence of the project with the existing urban planning scheme; analytical description of the production cycle of the plant; description of related works and infrastructures; survey of inhabited centres and cultural and landscape heritage; plant energy balance (electrical efficiency, operating hours/year, annual producible electricity, annual producible thermal energy); monitoring, control and emergency management plan; plan to dispose of and restore the original locations, with clear quantification of disposal costs gross of possible revenues; plant maintenance program; organisation chart of the personnel assigned to the management of the plant (only in the case of use of waste); geological, hydro-geological, and geotechnical relationship; acoustic impact forecast report; copy of the authorisation request made to the Directorate General for Mineral and Energy Resources (Bologna province AU requirements, from https://www.cittametropolitana.bo.it/portale/Engine/RAServeFile.php/f/Procedimenti/mod_a_istanza.pdf.)

[5] They could do so lawfully since according to the subsidiarity principle central government and regions share competences on environment-related issues. The differences in guidelines that emerged among regions concerned, for instance, the required documentation and the number of institutions involved in the authorisation procedure, the assignment/delegation of administrative functions (centralised at the regional level, decentralised at the provincial level or mixed depending on plant size), the identification of territorial areas and environmental context not suitable for plants installation, the specification of needed environmental impact assessments in order to proceed with the authorisation.

[6] Exempted plants could then follow the "Procedura Abilitativa Semplificata".

[7] The partial exemptions consisted of extending the PAS regime up to either 200 kW or 1 MW for specific types of plants, typically those located in areas considered degraded (landfills, quarries, industrial areas, etc.), located on agricultural lands or integrated into canopies, acoustic barriers and certain types of building roofs.

[8] For details on the Italian feed-in premium system see Appendix B.

Table 1
Control variables and sources.

Variable	Time varying	Year used	Source
Population	Yes	2009–2013	ISTAT
Population aged 15–64	Yes	2009–2013	ISTAT
Taxable income	Yes	2009–2013	Ministero Economia e Finanze
Bank loans & branches	Yes	2009–2013	Banca d'Italia
Solar radiation	No	2010	European Commission
Public sector efficiency	No	2011	Giordano and Tommasino (2013)

Notes: the public sector efficiency score developed by Giordano and Tommasino (2013) refers to efficiency calculated across several public services (namely childcare, education, healthcare, civil justice and waste disposal).

data by municipality and quarter and focus on capacity newly installed in plants between 20 and 200 kW, since this is the class size targeted by the simplification reforms in our sample for which we are able to obtain a cleaner identification. These plants represented in 2008 77% of power installed across all incentivised plants, and beyond 95% in terms of number of plants.[9] Nowadays, this class size represents 25% of Italian PV capacity installed. During 2009–2013, its contribution to newly installed capacity in each quarter averaged 30% (Fig. A.2). Fig. A.3 shows the geographical distribution of cumulative installed capacity for this type of plants.

We further assemble a rich set of variables at the municipal level. Some of these are time-invariant and we use them to explore potential heterogeneous effects of the simplification reforms (e.g., solar, public sector efficiency).[10] Some others vary at the municipality/year level (e.g., population and its demographic structure, taxable income, the value of bank loans and the number of bank branches). Table 1 provides a summary of the sources we rely on. Table 2 displays summary statistics for all the variables employed in the analysis.

Since our evaluation is based on a −4/+3 quarters observation period around the implementation of each reform, our starting sample is given by the regional simplification reforms occurring during 2009q4/2012q1, namely those of: Abruzzo (DGR n.294 02/05/2011), Basilicata (DGR n.2260 29/12/2010), Calabria (DGR n.81 13/03/2012), Emilia-Romagna (DGR n.1514 24/10/2011), Friuli-Venezia Giulia (LR n.19 11/10/2012), Lazio (LR n.16 16/12/2011), Lombardia (DGR n.8/10622 25/11/2009), Sardegna (DGR n.27/16 01/06/2011), Sicilia (DPresR n.48 18/07/2012, art. 329 c. 1, 2 e 5), Trento (LP n.26 04/10/2012), Umbria (RR n.7 29/7/2011) and Veneto (LR n.13 8/7/2011). From the starting sample, we exclude the islands of Sicilia and Sardegna since our empirical strategy is based on a border diff-in-diff. Moreover, in an effort to keep our final sample free from confounding factors we exclude the region of Veneto (for additional details on this choice see Section 5).

4. Empirical strategy

The ideal empirical approach in the hypothetical case of a single region introducing the simplification reform at a given time would be a border diff-in-diff, where the treatment group is given by municipalities of the treated region close to the regional borders and the control group are the neighbouring ones located in non-treated regions.

Table 2
Summary statistics.

Variable	Mean	Std Dev	Min	Max
Population (thousands)	7.6	40.4	0	2617.2
Population aged 15–64 (thousands)’)	5.0	26.0	0	1686.6
Taxable income (p. c.)	20 412.0	3041.0	12 171.1	53 289.2
Bank loans (million €)	0.2	4.9	0	393.5
Bank branches	4.3	26.1	0	1570.4
Surface (km2)	38.4	51.0	0.7	1287.4
Solar radiation (W/m^2)	171.7	18.4	122.4	227.4
Newly installed plants (20–200) (#)	0.3	1.7	0	77
Newly installed capacity (20–200) (kW)	19.0	94.4	0	3767.7
N	7822			

Notes: the time varying variables are averaged over 2009–2013. Summary statistics for investment in PV plants refer to 2009. Average taxable income refers to the average person declaring positive income to the Italian tax agency. Numbers are rounded to the first decimal digit.

In a standard diff-in-diff, the inclusion of municipality fixed effects allows leveraging the time discontinuity and tackling potential time-invariant confounding factors, such as geographical characteristics: if these are less favourable for plants installation local governments may be less interested in introducing simplification reforms incentivising PV investment.[11] Similarly, the inclusion of time fixed effects allows taking care of confounding factors that vary over time but do not differ in a statistically significant way across space, such as technological advances driving declines in the costs of building a PV plant (Mazzanti et al. (2012) and Di Dio et al. (2015)). However, in a simple diff-in-diff, the coefficient could still be biased by the presence of confounding factors violating the common trends assumption. For example, a potential time and space-varying confounding factor is the attitude of the local population towards the environment. A more green-oriented population is more likely to vote for a local government who is willing to introduce the reform, but it is also more likely to install more photovoltaic plants, thus biasing the results in a standard DID setting. To eschew the remaining endogeneity concerns, we combine the DID with the Local Geographic Ignorability Design,[12] narrowing down the sample of compared municipalities and focusing on those that lie within a selected distance from the regional border. If the selected distance is small enough, and included municipalities are marginal with respect to the whole region, it is unlikely that the adoption of the policy at the regional level is endogenous to their characteristics.[13] Moreover, since the treatment and control group are interconnected, share similar

---

[9] We are able to obtain a cleaner identification for plants between 20 and 200 kW for two reasons. Firstly, because while all regions introduced a full waiver from the Autorizzazione Unica for plants up to 200 kW, only a subset extended it up to 1 MW (often with many exceptions). Secondly, by focusing on the 20–200 kW range we minimise the risk of plant sorting across the border (see Section 5), which would bring to an overestimation of the effect of the simplification reforms. This risk is less relevant in the case of 20–200 kW sized plants, which are typically installed by condominiums or firms operating in the non-energy sector, since the location of these plants is constrained by the location of condominiums/firms.

[10] The public sector efficiency variable in Giordano and Tommasino (2013) is available at province-level.

[11] E.g., PV plants installation is lower in regions that are hillier or where the portion of land covered by agricultural crops/surface water is greater (ECORYS, 2010).

[12] Notice that we do not employ a Geographic Regression Discontinuity Design because the data are aggregated at municipality level, hence our spatial running variable would be discrete. See Keele and Titiunik (2015b,a) for additional details on both methods and Keele et al. (2017) for the Geographic RD with a discrete running variable.

[13] Going back to the example above, if we focus on the municipalities close to the border, the included municipalities represent a small portion of total regional population, too small to be decisive in regional elections.

geographical characteristics and have access to the same services, their outcome will plausibly follow parallel trends.[14] Fig. A.4 provides an example of the municipalities included for the region of Lombardia when applying distance $d = 30$ km.

In practice, since P regions passed the simplification reform and did so in different months and years during our observation period, we have many quasi-experiments that we can exploit.[15] To estimate the average treatment effect, we follow Autor et al. (2006) and carry out a single estimation on the $p \in \{1, 2, \dots, P\}$ "regional" balanced panels stacked together, each one composed of municipalities located in treated region p within distance d from the border and their corresponding control municipalities, also located within distance d from the border, observed within $-4/+3$ quarters window.[16] The estimating equation then is:

$$y_{ipt} = \gamma_{ip} + \sum_{b_p=1}^{B_p} \gamma_{b_pt} + \beta Treat_{ip} \times Post_{pt} + \epsilon_{ipt} \tag{1}$$

where y_{ipt} denotes the log of newly installed capacity in plants between 20 and 200 kW in municipality i, panel p and quarter t, γ_{ip} and γ_{b_pt} are, respectively, municipality-panel and border-quarter fixed effects.[17] $Treat_{ip}$ is a dummy variable identifying the treated municipalities in each regional panel, $Post_{pt}$ is a dummy variable identifying the post-treatment period in each regional panel, and ϵ_{ipt} is the error term. Our coefficient of interest identifying the impact of regional simplification reforms on PV investment is β. Municipality fixed effects are defined at the panel level since a given municipality might act as control municipality in multiple regional panels at the same time.[18] Similarly, quarter fixed effects are defined at the border level since a given quarter may belong to the evaluation period in multiple regional panels.[19] On top of adopting a fixed-length evaluation window, we exclude from the sample of control municipalities those belonging to regions switching treatment status during the evaluation period.[20] These precautions allow us to eschew most of the issues associated with the use of standard two-way-fixed-effects models in the presence of heterogeneous treatment effects (de Chaisemartin and D'Haultfoeuille (2022) and Roth et al. (2022)). Indeed, our model is a weighted average of the treatment effect for each regional panel weighted according to the number of municipalities it includes. A remaining concern may come from the use of early treated as controls. This may bias the results in the presence of a treatment effect changing over time. However, the empirical evidence suggests that the effect is quite stable over time (see Section 5). Finally, our results are robust to the exclusion of regional panels including early treated municipalities among the controls (see Table A.2).

Table 3
Alternative specifications for newly installed capacity.

	DiD	Border DiD	Excluding sorting	Covariates	Time-het.
$Treat_{ip} \times Post_{pt}$	0.273***	0.290***	0.298**	0.250**	
	(0.069)	(0.095)	(0.122)	(0.099)	
$Treat_{ip} \times Post_{p1st}$					0.361**
					(0.143)
$Treat_{ip} \times Post_{p2nd}$					0.158*
					(0.129)
$Treat_{ip} \times Post_{p3rd}$					0.351**
					(0.137)
Munic-Panel FE	YES	YES	YES	YES	YES
Border-quarter FE	YES	YES	YES	YES	YES
N	98 756	29 904	19 019	28 316	29 904

Notes: estimated coefficients from a simple diff-in-diff (col.1); from Eq. (1) for $d = 30$ km (col.2); from Eq. (1) excluding municipalities within 10 km from the border (col.3); from Eq. (1) for $d = 30$ km including covariates (population, population aged 15–64, average income, bank loans, number of bank branches); from Eq. (1) for $d = 30$ km estimating separate coefficients for each of the three post-treatment quarters (col.5). Standard errors clustered at the municipality level.

5. Results

The estimated coefficient from a simple diff-in-diff without restricting the sample to municipalities located close to the border is .27 and statistically significant, which implies an increase by 27 percentage points in newly installed PV capacity in treated municipalities after the treatment (col.1 of Table 3). Moving to the border diff-in-diff specification in Eq. (1), using only municipalities less than 30 km distant from the border entails a mild increase in the estimated coefficient up to 29% (col.2). The coefficient is only mildly larger when we exclude municipalities within 10 km from either side of the border, that might be exposed to potential sorting of plants (col.3). The coefficient drops to .25 when including time-varying covariates as controls (col.4). The impact of simplification reforms does not appear to follow a trend in treatment time (col.5).[21]

Fig. 2 and Table A.1 display the coefficient of interest obtained from estimation of Eq. (1) for different values of distance from the border ($d = 10, 20, \dots, 60$ km), showing that the estimated impact is not sensible to a variation in the distance to the border (within 60 km). The coefficient of interest is positive and statistically significant for $d \geq 30$ km. For shorter distances, the standard errors are particularly large and we interpret the absence of statistical significance as the result of lack of precision due to the much reduced sample.

The estimated impact is not only statistically but also economically significant, amounting to 12 extra MW installed per quarter, about 10% of average quarterly installations for the same category of plants during 2009–2013.

Results are unchanged when we perform a leave-one-out exercise, dropping in turn each of the nine panels present in our dataset

---

[14] These services include the electricity infrastructure, which in the case of Italy is administered centrally by the national Transmission System Operator (Terna Spa).

[15] Specifically, the regional reforms we evaluate are: Abruzzo, Basilicata, Calabria, Emilia-Romagna (ER), Friuli-Venezia Giulia (FVG), Lazio, Lombardia, Trento and Umbria. See the discussion at the end of Section 3.

[16] We believe a $-4/+3$ quarters window is sufficiently long for the effect produced by the reforms to play out. Meanwhile, it allows to minimise the number of early/late-treated controls that we have to drop because they switch the treatment status during the evaluation window. For other applications of the stacked diff-in-diff methodology see also Deshpande and Li (2019), Cengiz et al. (2019) and Vannutelli (2022).

[17] More precisely, to account for the presence of zeros in the data, we use as dependent variable the log of newly installed capacity plus 0.001.

[18] E.g., municipalities located in the region of Marche act as control municipalities for the regional reforms of both Emilia-Romagna and Umbria at the same time.

[19] E.g., 2009q4 is a post-treatment quarter in the Lombardia regional panel and pre-treatment in the Basilicata regional panel.

[20] Suppose that region A introduce the reform at time T. The panel corresponding to region A will include the municipalities within 30 km from the border of the neighbouring regions over the time span [T − 4: T + 2]. However, if one of the neighbouring regions implements the reform in any period falling inside [T − 4: T + 2], we excluded the municipalities located around the corresponding border from both the treatment and control group.

[21] We considered alternatively a longer time window of +/− 8 quarters, and estimated quarter-specific treatment effects as in col.5 of Table 3. We are unable also in that case to detect significant time variation in the estimated coefficients. Finally, we repeated the estimation by adding also pre-treatment time specific treatment dummies to investigate any statistically significant pre-trend in the treatment group. The pre-treatment time specific treatment dummies are close to zero and we can detect no statistically significant trend, thus suggesting the absence of pre-trends. These robustness checks are available upon request.

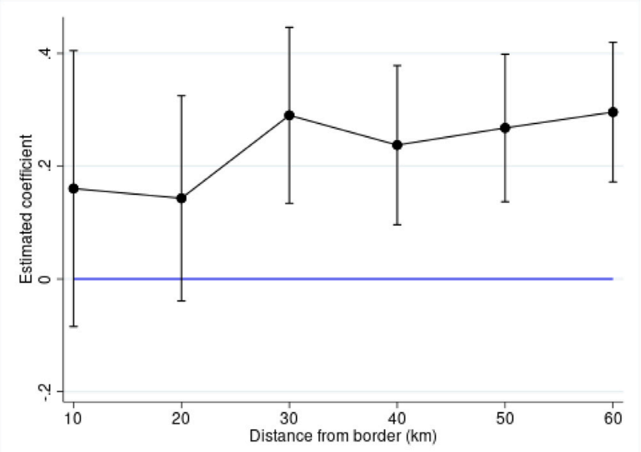


Fig. 2. Estimated impact of simplification reforms on installed capacity: baseline results. Notes: estimated coefficients from Eq. (1). 90% confidence intervals based on standard errors clustered at municipality level.

and re-estimating Eq. (1) (Table A.2). Based on the estimated coefficients reported in Table A.1, simplification reforms triggered a 15% increase in the number of medium-sized plants installed in the treated municipalities.

During 2009–2013, Italy also had in place a subsidy scheme for investment in PV plants characterised by a declining and discontinuous subsidy schedule (Fig. B.1) attached to a feed-in premium mechanism, the Conto Energia.[22] The biggest decline in the subsidy scheme happened between the 2nd and the 3rd Conto Energia (for details see Appendix B). It was preceded by a boom in capacity installed, as potential investors raced to get their plant connected to the grid before the switch to the less generous subsidy schedule went into effect (Fig. B.2). Although the change took place at the national level, prospective investors might have managed to take better advantage of the last months during which the more generous incentive scheme was still in place in regions that enjoyed a good level of administrative efficiency. Therefore, our results may be biased if the timing of the decline overlap with the pre-/post-treatment window and the treated and the control regions have different level of administrative efficiency. When the last months before the decline fall in pre-treatment period we can check whether this is the case looking to the pre-parallel trends in Table 6. If these are satisfied, we can conclude that the decline did not impact differently the capacity installed by the treated and the control regions. This is the case of Umbria, Emilia-Romagna, Lazio and Basilicata. Veneto region, instead, fails to pass this test (results are available upon request), thus convincing us to drop it from the set of reforms evaluated in this paper. We have a trickier problem if the last months before the decline fall in post-treatment period, as for Basilicata and Abruzzo. We cannot establish whether the estimated effect is due to the simplification reform or to the fact that these regions have different administrative efficiency compared to their neighbours. As a solution, we check the sensitivity of our results to the exclusion of the corresponding panels from the sample. As we show in the last row of Table A.2, the results are robust to the exclusion of the two panels.

Another potential threat to our estimation is the presence of plant sorting. Sorting of investors would indeed translate into a coefficient decreasing when the distance from the border increases and an overestimation of the causal impact of simplification reforms at the border. Our evidence showing that the estimated coefficient is instead weakly increasing in the distance from the border suggests that this mechanism is unlikely to be a concern in our case. This is further confirmed when we exclude municipalities closer to the border: in this case the estimated coefficient rises to 30%, 1 percentage points higher than in the baseline border diff-in-diff specification (comparison between col.2 and col.3 of Table 3).

The simplification reforms so far analysed increased the relative convenience of building a plant with capacity above 20 kW vs. one with capacity below 20 kW. Plants with capacity between 10 and 20 kW were not targeted by the simplification reforms. While before the reforms it was easier to build these plants relative to larger ones, after the reforms they lost this comparative advantage. Hence, to what extent the expansion in investment into medium-size plants took place at the expenses of smaller ones? To answer this question, we re-estimate Eq. (1) on the subset of new plants with capacity between 10 and 20 kW, $k \in [10, 20)$. The estimated coefficients are reported in Table A.3. The coefficient measuring the double difference in investment into smaller plants (before/after the simplification reforms and between one side and the other of the border) is never statistically significant, independently from the distance to the border considered, thus suggesting the absence of displacement effects.

A second and more precise test for the absence of displacement effects we can perform consists of estimating the extent of "bunching" (Kleven, 2016) in the plant size distribution before and after the regional simplification reforms for each of the regions that enacted them. The presence of a declining "notched" subsidy schedule, i.e., a discontinuous schedule with breaks at fixed capacity thresholds, has been shown to give rise to bunching in the plant size distribution (Germeshausen, 2018), namely to displace investment from larger to smaller plants (Kleven, 2016). In the presence of bunching, there is a subset of "bunching" plants that would have been built with higher capacity in the presence of a uniform subsidy. In practice, however, given that building a larger plant with a notched subsidy schedule entails losing access to the more generous subsidy granted to plants with capacity equal to the threshold, investors of "bunching" plants prefer investing in plants with capacity equal to the threshold.

The conceptual framework proposed in Appendix C featuring the interplay between a simplification reform and a notched subsidy schedule predicts that a simplification reform in the form of a reduction in the sunk cost of building a medium-sized plant should have no impact on the extent of bunching: provided that these reforms do not affect the subsidy schedule, the plant capacity decision should be independent of the sunk cost, since once the latter is paid investors have the incentive to choose the optimal plant size, which depends exclusively on the variable cost. Nevertheless, acknowledging the stylised nature of our model, we proceed by testing whether the extent of bunching went down and in a statistically significant way after the reforms were enacted.

We start by empirically measuring the extent of bunching at the 20 kW threshold in the plant size distribution in the treated regions before the reforms. In practice, this amounts to using the portion of the plant size distribution unaffected by bunching to fit parametrically the plant size distribution, and quantifying the excess mass caused by bunching at the threshold as the difference between the observed and the fitted distribution. Appendix C contains the details of the estimation. Figs. 3 and A.5 in the Appendix confirm the existence of bunching in the plant size distribution in all treated regions. The estimated coefficient for a given region measures the excess mass relative to the total number of plants part the distribution. For example, the interpretation of the coefficient of 0.015 for Lazio is that

---

[22] In a feed-in tariff (FIT) system, power plant operators receive a fixed payment for each unit of electricity generated independent of the electricity market price. In a feed-in premium (FIP) system, plant operators have to market the electricity generated directly at the electricity market and receive an additional payment on top of the electricity market price, either as a fixed payment or adapted to changing market prices in order to limit both the price risks for plant operators and the risks of providing windfall profits at the same time (ECOFYS, 2013).

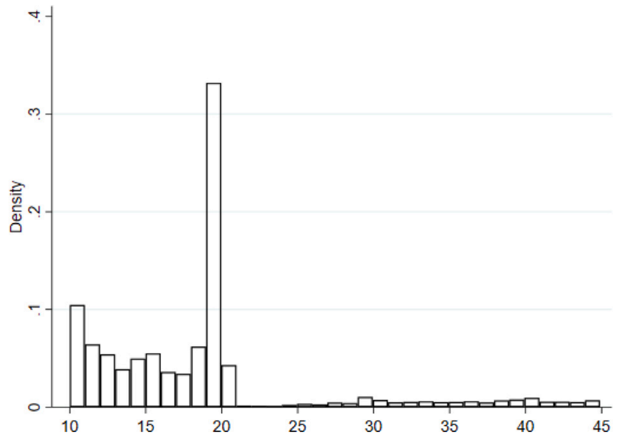


Fig. 3. Installed capacity distribution around the 20 kW threshold in the pre-treatment period in treated regions. Notes: each histogram bin has 1 kW width.

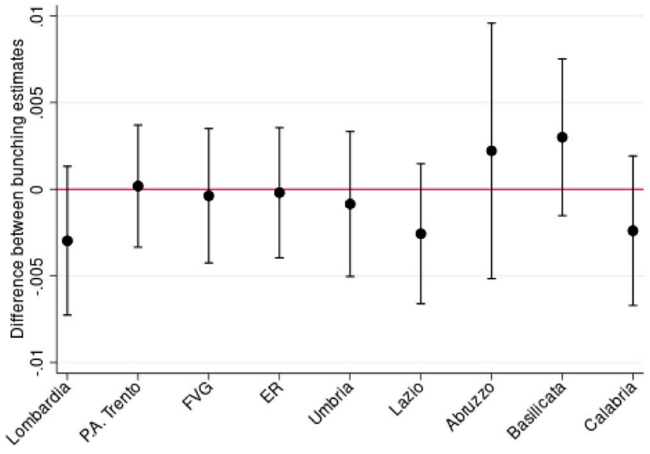


Fig. 4. Changes in bunching before/after the implementation of the simplification reforms. Notes: 90% confidence intervals based on bootstrapped standard errors.

the number of plants at the 20 kW threshold in “excess” is 1.5% × 6448 (the total number of plants in the region) = 97 plants (Fig. A.5).

Later on, we compare the bunching estimated before the reform with those estimated after. We believe that this test allows us to test more directly the possibility that after the simplification reforms a number of plants was installed with capacity greater than 20 kW whereby these plants would have been built regardless of the reforms at capacity equal to 20 kW. Fig. 4 shows the estimated difference in the extent of bunching before and after for the nine regions considered and the associated confidence interval bands.

The difference is always negative except for Abruzzo and Basilicata, but never statistically significant, thus confirming that displacement is unlikely to a be a concern in our setting. The reason for why the estimated difference is positive for Abruzzo and Basilicata is that the post-treatment period for these two regions includes 2011q2, the quarter before the switch away from the generous incentive scheme known as 2nd Conto Energia.

5.1. Heterogeneous effects

Table 4
Heterogeneous impact of simplification reforms on newly installed capacity.

	Solar radiation	Public sector efficiency	Complete
$Treatment_{ip} \times After_{pt}$	0.211*	0.383**	0.199*
	(0.108)	(0.150)	(0.112)
$Treatment_{ip} \times After_{pt} \times d_b$	0.268	−0.142	0.221
	(0.221)	(0.182)	(0.196)
N	29 904	29 904	29 904

Notes: coefficients from the estimation of Eq. (2) for $d = 30$ km. Clustered standard errors in parentheses. Statistical significance: * 0.10 ** 0.05 *** 0.01.

Next, we explore the heterogeneity of the estimated coefficients with respect to a set of time-invariant municipality characteristics that we deem of economic interest in this context. In order to do so, we augment the baseline regression as follows:

$$y_{ipt} = \gamma_{ip} + \sum_{b_p=1}^{B_p} \delta_{b_p t} + \beta_1 Treatment_{ip} \times After_{pt} + \beta_2 (Treatment_{ip} \times After_{pt} \times d_b) + \epsilon_{ipt} \quad (2)$$

where $d_b = 1$ if municipality i is close to a border b (1) characterised by higher than median solar radiation, (2) characterised by higher than median public sector efficiency, (3) belonging to regions implementing a complete simplification reform (i.e., Abruzzo, Basilicata, Calabria, Friuli-Venezia Giulia, Lazio and the autonomous province of Trento) vs. a partial simplification reform (i.e., Emilia-Romagna, Lombardia, Umbria).

Table 4 shows the output of the heterogeneity analysis. We find that the impact of simplification reforms has been higher but not in a statistically significant way along borders characterised by higher solar radiation (col.1) Hence, the policy was effective at raising PV investment but not necessarily efficient, in the sense of spurring the investment rate particularly in areas of the country where the yield - in terms of electricity generation - was the highest.[23] Conversely, we are unable to detect a statistically significant heterogeneous effect based on the degree of public sector efficiency (col.2), or the depth of simplification reforms (col.3). Concerning the former, the sign of a potential heterogeneous effect might indeed go in either direction. On the one hand, simplification reforms might unlock investment in territories where the gap with the optimal investment level due to administrative inefficiency was particularly high. On the other, territories characterised by higher administrative efficiency might be better positioned to take advantage of simplification reforms (Barca et al., 2012). Concerning the latter, we explain the absence of a statistically significant difference in the implementation of a complete vs. a partial simplification reform by the fact that in the majority of cases the constraints that partial reforms did not relax applied to larger plants (between 200 and 1000 kW of capacity installed).

6. Testing assumptions validity

The two main identifying assumption of our model are: (1) all potential outcomes must be independent from the treatment within the selected distance from the border[24]; (2) the effect of confounding factors and of different characteristics between treated and control municipalities must be constant over time within the selected distance from the border (i.e., the parallel trends assumption).

---

[23] This result is perhaps not very surprising, as we know the spatial distribution of PV installed capacity at the national level (visible here: https://www.terna.it/it/sistema-elettrico/dispacciamento/fonti-rinnovabili) follows the distribution of natural resources much less than alternative renewable energy sources, such as wind turbines. In our sample, the raw correlation between the average of quarterly installations at the municipal level and solar radiation is less than 5%.

[24] We adapted the diff-in-disc assumptions of Grembi et al. (2016) to our local quasi-experimental setting following Keele and Titiunik (2015b,a).

Table 5
Observables balance test by distance from the border: min p-values among regional panels.

Distance	Population	Population aged 15–64	Taxable income per capita	Bank loans	Bank branches
10	1	1	1	1	1
20	1	1	1	1	1
30	0.41	0.51	1	1	1
40	0.31	0.14	1	1	1
50	1	1	1	1	1
60	1	1	1	1	1

Notes: we run a border diff-in-diff regression akin to Eq. (1) using the selected observables as outcomes based on a single pre/post-treatment period. We adjust the p-values of our coefficient of interest using the Bonferroni correction for multiple testing. Standard errors were clustered at a municipality level.

Table 6
Parallel trends test in the pre-treatment period by distance from the border.

Distance	Coefficient	SE	N
10	0.224	(0.226)	6220
20	−0.033	(0.173)	11 844
30	−0.085	(0.146)	17 088
40	−0.032	(0.130)	22 268
50	0.021	(0.119)	27 340
60	0.061	(0.112)	31 912

Notes: we run Eq. (1) on pre-treatment data. We use the first three quarters of the pre-treatment period as placebo pre-treatment period and the fourth quarter as placebo post-treatment period. Standard errors were clustered at a municipality level.

The first assumption may be violated if regional governments decision on whether to introduce the reform or not are determined by the characteristics of municipalities around the borders and these differ in a statistically significant way across the border. This is unlikely to be the case for two reasons. First, as already mentioned, regional governments decisions are unlikely to be taken based on the characteristics of a subset of municipalities. As a proof, we checked what is the weight at the regional level of the municipalities included in the estimation. Municipalities located within 30 km from the border account for between 14% and 39% of regional population across all regions (Table A.4). This evidence lends credibility to our choice of setting this distance to the border as the baseline, in an effort to balance sample size considerations and endogeneity concerns. Second, the characteristics of municipalities on either side of the border are likely to be similar: their economies are highly interconnected, they share similar geographical characteristics and have access to the same services. We partially test this statement by carrying out balance tests on a set of observables for each panel. Following Grembi et al. (2016), we re-estimate the baseline equation using observables as outcomes. The results are provided in Table 5, where we display the minimum *p*-value across the nine regional panels for each observable used. Panels appear to be balanced at least up to 60 km from the border, which suggests that the first assumption might be satisfied in our setting.

The parallel trends assumption is also likely to hold given the short time period we are considering. Nevertheless, we partially test this assumption by re-estimating the baseline equation on pre-treatment data: all the estimated coefficients are not statistically significant and, more importantly, the magnitude of the coefficients is meaningfully smaller (Table 6). This evidence confirms parallel trends in the treated and control group in the pre-period, making thus plausible to assume that they would be parallel in the post-treatment period as well.[25]

The validity of the stacked design requires making two additional assumptions (Autor et al., 2006): (3) the treatment effect is constant during the interval considered, and (4) the municipalities used as controls do not change treatment status while acting as controls. The stability of the treatment effect during the interval considered is likely to be satisfied given the short time period considered around the reform (a window of 4 pre- and 3 post-treatment periods). According to the last column of Table 3, the treatment effect is fairly stable throughout the first three periods after treatment.

The fourth and last requirement concerns the exclusion from the control group of regions changing treatment status while acting as controls. As a matter of fact, multiple regions change status at a time when they could act as control for other regions treated earlier on. We drop all the borders involved with a minor exception. Specifically, we exclude: the Lazio/Abruzzo border from the Abruzzo panel and the Abruzzo/Lazio border from the Lazio panel, the Veneto/Emilia-Romagna from the Emilia-Romagna panel, the Lazio/Umbria border from the Umbria panel and the Umbria/Lazio border from the Lazio panel. The Basilicata/Calabria border is the minor exception: in April 2010 the Constitutional Court declared unlawful a regulatory simplification law passed in 2008 by the region of Calabria, which acts during that time as control region for Basilicata. We decided to retain the Basilicata/Calabria border since the policy change took place during the first month during which Calabria is acting as control region for Basilicata (2010q2-2011q3). The results are nevertheless robust to the exclusion of the Basilicata panel from the sample (see Table A.2 in the Appendix).

7. Discussions and policy implications

While being essential for the economy's functioning and the achievement of public's objectives, particularly in areas of health, safety and environmental protection, excessively burdensome and costly regulation can be detrimental to economic development (OECD, 2003).

In the field of RES development, the main goal of the permitting process is to protect human health and the environment by defining legally binding requirements for industrial installations of significant environmental impact. In its absence, the installation of industrial plants could involve environmental damages and social costs exceeding the related benefits, with detrimental effects on societal well-being. The permitting process requires indeed an environmental impact assessment for large scale plants (generally defined as plants with capacity installed above 1 MW). In order to further strengthen environmental protection, regions can decide to reduce this threshold and/or identify suitable/unsuitable areas where the development of renewable plants is authorised, whereby 13 Italian regions have proceeded in this sense.

Regulation should thus be efficient, implying a right balance between the social costs and benefits of renewable investment, and it should not be taken for granted that regulatory simplifications fastening the diffusion of renewable plants increase social welfare. While developing an accurate and comprehensive social cost–benefit analysis goes beyond the scope of this paper, a discussion of RES development social costs and benefits can provide useful arguments to address the question on whether the regulatory simplification analysed in this research, on top of being effective, was efficient as well.

On the benefit side, the replacement of fossil fuels-based energy production with renewable technologies promotes a reduction of greenhouse gas emissions and local pollutants (both harmful chemicals, such as heavy metals and particles, PM2.5, PM10, and harmful gases SO, NO_x). Moreover, it is associated with increased energy security and a

---

[25] The inclusion of Veneto in the sample would cause the coefficients to be statistically significant above 40 km from the border and extremely higher in magnitude for any distance from the border (results are available upon request). The fact that the last pre-treatment period quarter in Veneto was 2011q2 - the quarter of the artificial PV boom triggered by the expiration of the 2nd Conto Energia - potentially explains the absence of parallel trends in the pre-treatment period for this region. The (just motivated) failure of the parallel trends assumption to hold for this region justifies our choice of excluding it from our sample. See Section 3 for more details.

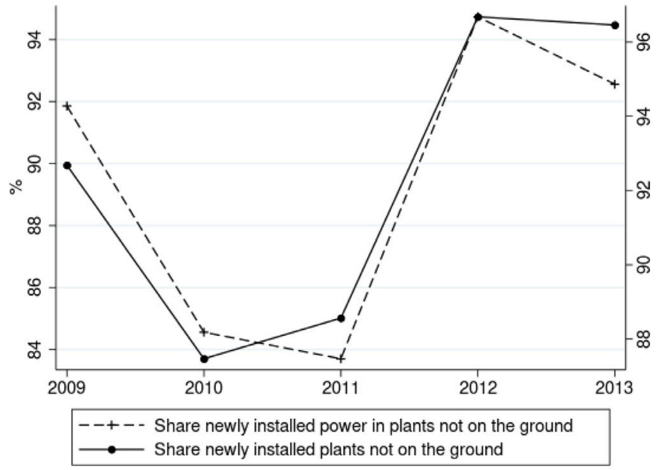


Fig. 5. Share of power (number of plants) installed not on the ground.
Source: Gestore Servizi Energetici.

decreased dependency from fossil fuels imported often from countries that are not democratic and often do not guarantee fundamental human rights. Third, it has been acknowledged that RES investments have non-negligible innovative dynamic effects. According to various estimates, solar average LCOE declined by almost 90% in a decade thanks to significant learning-by-doing effects, making PV technology cost-competitive with fossil fuel–based ones (IRENA, 2020). Social benefits shall account for both new market opportunities and the decline in the price for renewable energy (Gelabert et al., 2011 and Clò et al., 2015).

The installation of RES plants can impose costs on local residents (Meyerhoff et al., 2010). For instance, visual and noise-related disamenities that can get reflected into a reduction in the property values, with a heterogeneous effect depending on the type of renewable source, the size of the plant and its proximity. These effects are found to be relevant mainly for wind turbines and utility-scale solar plants (Gibbons, 2015 and Parsons and Heintzelman, 2022), which importantly do not represent the object of our analysis. On the contrary, small-sized PV panels even are found to increase property values when installed on properties' rooftop (Hoen et al., 2012 and Qiu et al., 2017)

The rapid expansion of solar farms in rural areas with ground-installed PV panels has furthermore raised the concern of the potential negative effect on agricultural land values, production and food prices (Owley and Morris, 2019). Recently, Abashidze and Taylor (2022) estimated that solar farms do not have negative effects on nearby agricultural land values. These potential costs are in any case unlikely to apply to the plants considered for this study, which are in 95% of cases not installed on the ground (Fig. 5).

Negative implications in terms of loss of biodiversity and ecosystems deterioration can derive from large-scale plants, such as wind turbines (Voigt et al., 2019), while they are not relevant for small to medium-sized PV panels. Finally, the penetration of intermittent and non-programmable renewable sources has sharpened the issue of continuous balancing between the amount of electricity injected into and withdrawn from the electricity grid, inducing the Transmission System Operator to increase its activity in the balancing markets with increased systemic costs (Clò and Fumagalli, 2019). Again, these costs are more likely to be associated with utility-scale plants that are connected to the high-voltage transmission grid and that bid actively in the wholesale power exchange as opposed to small-sized plants connected to the low-medium voltage distribution grid, such as the plants that are the object of our study.

To conclude, the literature widely agrees that the main negative effects of RES technologies on the environment, land or property values almost exclusively derive from large scale plants, such as wind turbines, solar farms, commercial or utility-scale plants, while they are less likely to be relevant in the case of small to medium-sized PV panels that are the object of our analysis. Given the limited negative externalities stemming from the latter, we can reasonably argue that the introduction of a simplified authorisation procedure such as the one considered in this research is likely to enhance social welfare.

Finally, our analysis brings some useful insights to evaluate recent policies and reforms proposed at the European level to promote the scaling-up of RES technologies. On May 2022, the European Commission (EC) published the RepowerEU with the clear intent of accelerating the roll-out of renewables, whose 2030 targets have been further increased up to 45% under the Fit for 55 package. A dedicated EU Solar Strategy has been designed with the aim of doubling solar PV capacity by 2025 and installing 600 GW by 2030 (from 209 GW in 2022). Renewable energy projects have been declared by the EC “of overriding public interest and serving public health and safety”. Moreover, the RepowerEU has included an explicit recommendation for countries to adopt the most favourable procedure available among their planning and permit-granting established procedures. Both actions seem to suggest the acknowledgement on the behalf of the EC that RES benefits outweigh the related costs. Being the simplification reforms evaluated in this paper and those proposed by the EC quite similar, the results of our analysis suggest that the EC permit-granting procedure simplification is likely to promote additional investments on small to medium-sized PV panels with welfare improving effects.

Our findings have concrete implications applicable also outside of Europe. In the United States, consumers willing to install rooftop solar panels are nowadays still expected to wait around 25–100 days from the permit application date until installation, with substantial municipality and state-level heterogeneity. Greater standardisation in the permitting procedures at the national level on the lines of the legislative innovation analysed in this paper would likely reduce average permit duration and boost PV adoption (O'Shaughnessy et al., 2020).

8. Conclusion

The European legislation sets a very ambitious goal for 2030 in terms of photovoltaic installation. Accelerating renewable energy deployment is important not only from a sustainability point of view but also to increase energy independence from imported fossil fuels and reduce the impact of fluctuations in their prices on our economy. Financial incentives alone seem not to be sufficient to reach this goal. Indeed, although the average levelised cost of energy of utility-scale solar photovoltaic fell 82% between 2010 and 2019 (IRENA, 2020), photovoltaic growth has been sluggish in those years, in spite of the available financial subsidies. It is therefore crucial to investigate the effectiveness of other policies to boost renewable energy sources, which are of non-financial nature and concern the administrative barriers introduced by the regulatory framework. The last type of policies is the focus of this paper.

This paper shows that during the years of photovoltaic boom in Italy (2009–2013), the regions that introduced regulatory simplification reforms for the installation of medium-sized (20–200 kW) photovoltaic plants experienced a 29% increase in capacity installed. This translated into 12 extra MW installed per quarter at the aggregate level, about 10% of average quarterly installations for the same category of plants during the period under consideration. While effective, the policy was not equally efficient, as it did not manage to spur photovoltaic investment in regions characterised by high solar radiation.

Our work shows that regulatory simplification measures are effective in supporting the deployment of small to medium-sized plants. Furthermore, it argues in favour of these benefits likely outweighing potential socio-economic costs and therefore of the efficiency of these measures from a social perspective. The findings enrich the debate surrounding the permitting simplification measures proposed by the

Table A.1
Baseline border regression: coefficient estimates by distance from the border.

Distance	Newly installed capacity		Number of plants		N
	Coefficient	SE	Coefficient	SE	
10	0.160	(0.149)	0.094	(0.094)	10 885
20	0.143	(0.111)	0.085	(0.070)	20 727
30	0.290	(0.095)	0.177	(0.060)	29 904
40	0.237	(0.086)	0.144	(0.054)	38 969
50	0.268	(0.080)	0.164	(0.050)	47 845
60	0.296	(0.076)	0.181	(0.048)	55 846

Notes: estimated coefficients from Eq. (1). Standard errors are clustered at municipality level.

Table A.2
Leave-one-out robustness checks.

Excluded sample	Coefficient	SE	N
Basilicata	0.300	(0.097)	27 615
Abruzzo	0.249	(0.098)	27 853
Lazio	0.283	(0.098)	28 441
Calabria	0.276	(0.095)	29 218
FVG	0.260	(0.096)	28 252
Trento	0.318	(0.100)	26 047
Lombardia	0.432	(0.139)	19 201
Umbria	0.243	(0.096)	28 483
ER	0.303	(0.098)	24 122
Abruzzo and Basilicata	0.256	(.100)	15 564
ET Panel	0.248	(0.097)	21 784

Notes: we run Eq. (1) for $d = 30$ km excluding one-by-one all samples. The first column record the treated region in the sample excluded. "FVG" stands for Friuli-Venezia Giulia, "ER" stands for Emilia-Romagna. "ET Panel" stands for early-treated panels, in the estimation we exclude all panels having early-treated among the controls. Standard errors are clustered at municipality level.

European Commission within the context of the REPowerEU package and provide useful empirical evidence in their support.

Finally, going forward it might be interesting to shed further light on the channels through which simplification reforms positively affect the investment rate, by relying for instance on more detailed data allowing to proxy for investment uncertainty or the burden related to the administrative process (e.g., data on applications that were filed but, in the end, not granted approval or data on permit duration).

CRediT authorship contribution statement

Federica Daniele: Conceptualization, Methodology, Software, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Supervision. **Alessandra Pasquini:** Conceptualization, Methodology, Software, Formal analysis, Writing – original draft, Writing – review & editing. **Stefano Clò:** Conceptualization, Data curation, Writing – original draft, methodology, Writing – review & editing, Project administration, Supervision. **Enza Maltese:** Conceptualization, Writing – original draft, Writing – review & editing.

Appendix A. Figures and tables

See Tables A.1–A.4 and Figs. A.1–A.5.

Table A.3
Displacement effect testing: border regression applied to new capacity installed in 10–20 kW plants, coefficient estimates.

Distance	Coefficient	SE	N
10	0.031	(0.149)	10 885
20	0.028	(0.112)	20 727
30	0.053	(0.095)	29 904
40	0.107	(0.087)	38 969
50	0.091	(0.081)	47 845
60	0.079	(0.077)	55 846

Notes: estimated coefficients from Eq. (1). Standard errors are clustered at municipality level. Plants with capacity between 10–20 kW were not targeted by the policy.

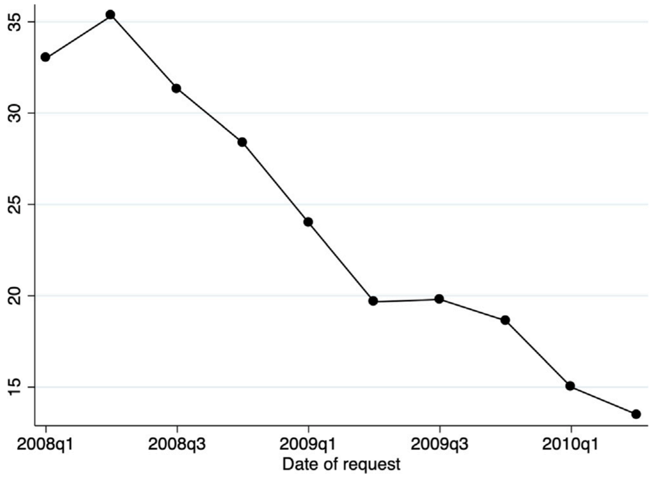


Fig. A.1. Time to obtain *Autorizzazione Unica* in the region of Puglia (months). *Source:* Webscraped from https://www.sistema.puglia.it/portal/page/portal/SistemaPuglia/AutorizzazioneUnica.

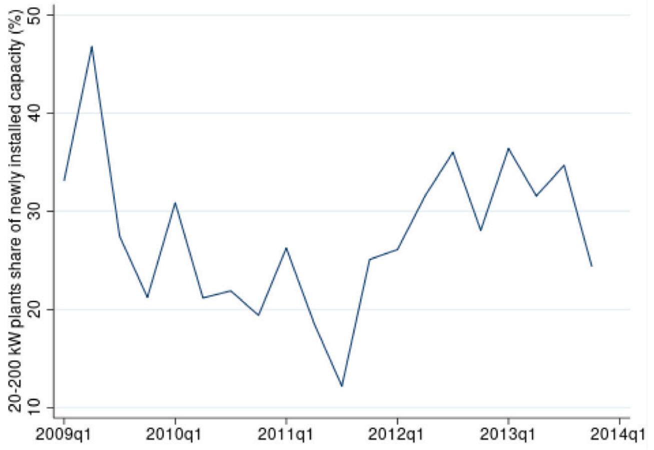


Fig. A.2. Share of newly installed capacity in 20–200 kW plants. Notes: the figure shows the ratio between capacity installed in a given quarter in medium-sized plants (20–200 kW) and capacity installed in a given quarter across all plants.
Source: Gestore Servizi Energetici.

Appendix B. Italian feed-in premium mechanism

In this section, we describe more in detail the Italian feed-in tariff mechanism that was in place during 2009–2012, the *Conto Energia* (CE). Under the "Conto Energia" (introduced by D.Lgs. 387/2003), the tariff depended on plant size (1–3 kW, 3–20 kW and bigger than 20 kW) and plant type (Fig. B.1), but was essentially uniform across regions. Five rounds of CE have been enacted during 2003/2012, each round essentially lowering the subsidy schedule compared to the previous one and thus accompanying technological advances that were making over time cheaper to invest in PV plants. The second round of CE became effective in February 2007. In August 2010, the so-called "Decreto Salva Alcoa" postponed from January to June 2011 the starting date of

Table A.4
Relative size of municipalities by distance to the border.

Distance	Lombardia	P.A. Trento	Friuli-Venezia Giulia	Emilia Romagna	Umbria	Lazio	Abruzzo	Basilicata	Calabria
10	11	3	7	6	6	4	7	5	6
20	22	9	15	12	11	8	14	9	10
30	39	17	22	23	17	14	24	15	14
40	51	25	33	34	22	18	31	25	20
50	62	31	44	47	28	28	41	36	24
60	70	37	53	57	58	57	81	41	30

Notes: each cell contains the % out of total regional population.

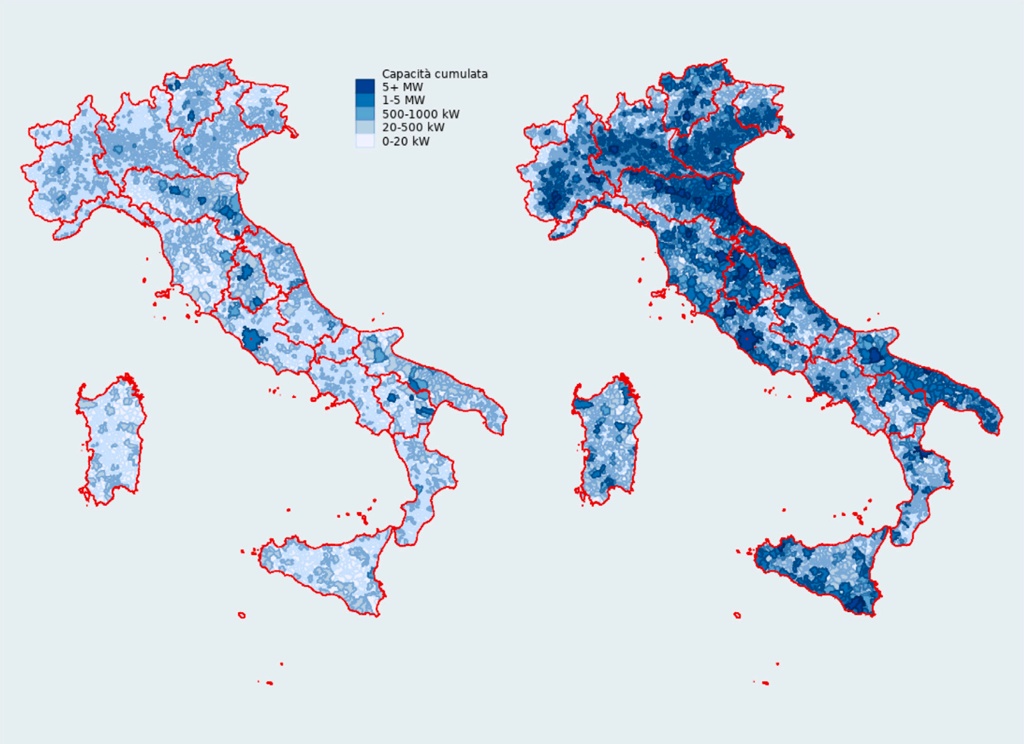


Fig. A.3. Cumulative installed capacity in 20–200 kW photovoltaic plans. Notes: the left (right) graph shows the distribution in 2009 (2013).
Source: Gestore Servizi Energetici.

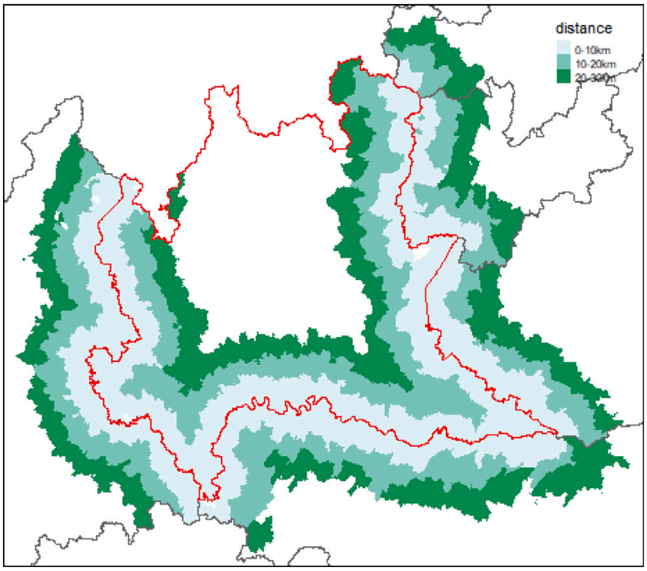


Fig. A.4. Example of border diff-in-diff applied to Lombardia.

the third CE, which was going to entail a major downward adjustment of the marginal tariff.[26]

In June 2011 and July 2012 two more rounds of CE (the fourth and fifth, respectively) came into force, both of which introduced reductions - although less significant than the one introduced by the third CE - in the overall subsidy schedule. Moreover, the fifth CE introduced a separate remuneration scheme for energy produced and consumed and energy sent instead to the grid, whereby the subsidies in place up to that moment went to the totality of energy produced, without distinction for the amount of energy consumed. In August 2013, the fifth and last version of CE expired since the statutory monetary ceiling for total subsidies volume had been reached.

Fig. B.2 (panel (a)) portrays the evolution of newly installed PV capacity. During the last decades, PV installed capacity increased from 0.031 GW in 2004 to 20.9 GW in 2019, which made Italy one of the countries with the fastest and most significant PV diffusion in the world. Most of this exponential growth was realised in a relatively short time lapse, over the period 2009–2013. During 2014–2019, only 0.45 GW/year were on average installed, while, according to the NECP,

---

[26] More specifically, it established that plants realised before 31 December 2010 and connected to the grid before the end of June 2011 could access the more generous subsidies disciplined by the second round of CE.

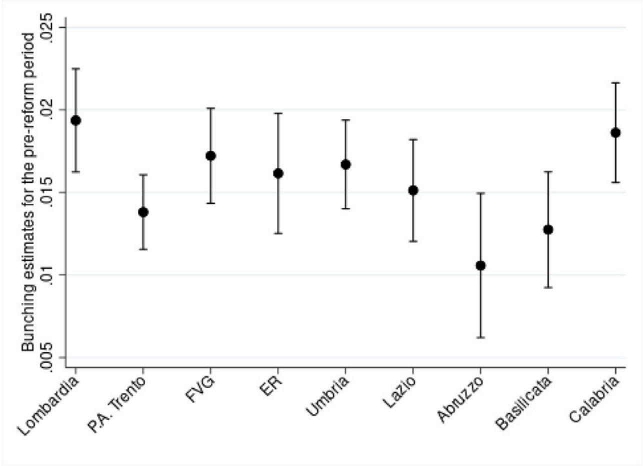


Fig. A.5. Extent of bunching before the implementation of the simplification reforms. Notes: 90% confidence intervals based on bootstrapped standard errors.

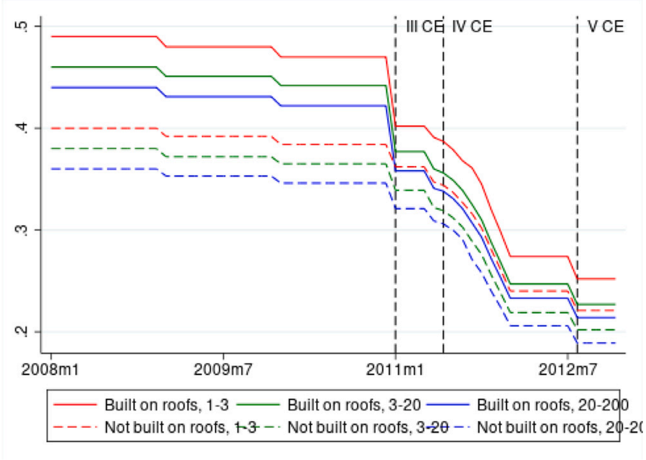


Fig. B.1. Evolution of subsidies incentivising investment in PV plants in Italy (EUR/kW).
Source: D.Lgs. 387/2003 (I Conto Energia), D.M. 19/02/2007 (II Conto Energia), D.M. 06/08/2010 (III Conto Energia), D.M. 05/05/2011 (IV Conto Energia), D.M. 05/07/2012 (V Conto Energia). The dashed lines are drawn in correspondence of the application starting date of the different Conto Energia: 2011m1 (III CE), 2011m6 (IV CE), 2012m8 (V CE).

at least 3 GW/year will have to be installed during 2021–2030. Importantly, PV growth has been sluggish in spite of PV energy having become an increasingly competitive option.[27]

The national evolution of newly installed PV capacity displays two spikes. The first one takes place in the months right before the expiration of the 2nd Conto Energia extension decreed by the “Decreto Salva Alcoa”. The “Decreto Salva Alcoa” (passed in August 2010) introduced the possibility for plants built by December 2010 but not yet connected to the grid to nonetheless benefit from the 2nd Conto Energia conditional on getting connected to the grid by June 2011. Since the 2nd Conto Energia tariffs were more generous than the ones introduced with the 3rd Conto Energia (applicable to plants connected to the grid starting from January 2011), many investors that had managed to build their plants by December 2010 hurried to get their plant connected by June 2011. The second spike occurs right before the introduction of the 5th Conto Energia, which also entailed a substantial reduction in the generosity of PV subsidies.

Fig. B.2 (panel (b)) portrays the evolution of new installed capacity broken down into class sizes: up to 20 kW, between 20 and 200 kW, between 200 kW and 1 MW, and above 1 MW. The two installation booms differ in terms of composition of the plants installed: the second wave has seen the rapid deployment of plants belonging to the 20–200 kW class size, as opposed to the first wave, which is characterised by a large incidence of very large plants being installed (above 1 MW).[28]

The tight link between the evolution over time of PV investment and the timing of different Conto Energia rounds is confirmed by Fig. B.3, which shows the percentage of newly installed plants subsidised under the different incentive schemes. In 2011q3 the percentage of plants subsidised under the 2nd Conto Energia newly drops virtually to zero, while in 2012q3 the percentage of plants subsidised under the 4th Conto Energia is substantially reduced.

Appendix C. Robustness to the interplay with other policies

C.1. A simple model of PV investment with the interplay of regulatory simplification and financial incentives

There is a continuum of M firms indexed by i and characterised by productivity A_i. They produce substitutable goods using energy K_i as an input according to a linear production function $Q_i = A_i K_t$. Firms compete in a monopolistic competition environment, while consumers' utility takes the form of a CES aggregator with elasticity of substitution σ. Then, the consumer first order condition is $Q_i = P_i^{-\sigma} P^{\sigma-1} Y = P_i^{-\sigma} \widetilde{Y}$, while the firm first order condition is $P_i = \left(\frac{\sigma}{\sigma-1}\right) MC_i$, with MC_i being the marginal cost. Firms that decide to build a PV plant receive a subsidy for each unit of energy they produce. The subsidy depends on the amount of energy produced, and it is equal to $\overline{s}$ for $K_i \leq K^*$ and $\underline{s}$ for $K_i > K^*$. Then, the marginal cost is:

$$MC(A_i) = \begin{cases} p/A_i & \text{if the firm chooses not to invest} \\ (c-\overline{s})/A_i & \text{if the firm chooses to invest and installs} \\ & \quad \text{energy } K_i \leq K^* \\ (c-\underline{s})/A_i & \text{if the firm chooses to invest and installs} \\ & \quad \text{energy } K_i > K^* \end{cases} \tag{C.1}$$

where p is the cost of purchasing one unit of energy from the grid and c is the cost of producing one unit of energy in-house. Finally, the firm who decides to invest needs to pay a sunk cost equal to:

$$f(A_i) = \begin{cases} \underline{f} & \text{if } K_i \leq K^* \\ \overline{f} & \text{if } K_i > K^* \end{cases} \tag{C.2}$$

Due to the notched subsidy schedule, the equilibrium will feature bunching, in the sense that there will be some firms that would have chosen to invest into a larger plant if the subsidy had not been lower for

---

[27] According to the International Renewable Energy Agency, thanks to the 90% reduction in its module prices, on average the levelised cost of electricity (LCOE) of utility-scale solar PV fell 82% between 2010 and 2019, becoming the cheapest option in almost all parts of the world (IRENA, 2020). The International Energy Agency recognises that, with a 30 USD/tCO2 carbon price, the PV's LCOE is lower than the costs of conventional fossil fuel generation (IEA, 2020).

[28] Overall, the incentives in place until December 2012 privileged medium-sized to large plants (Antonelli and Desideri, 2014).

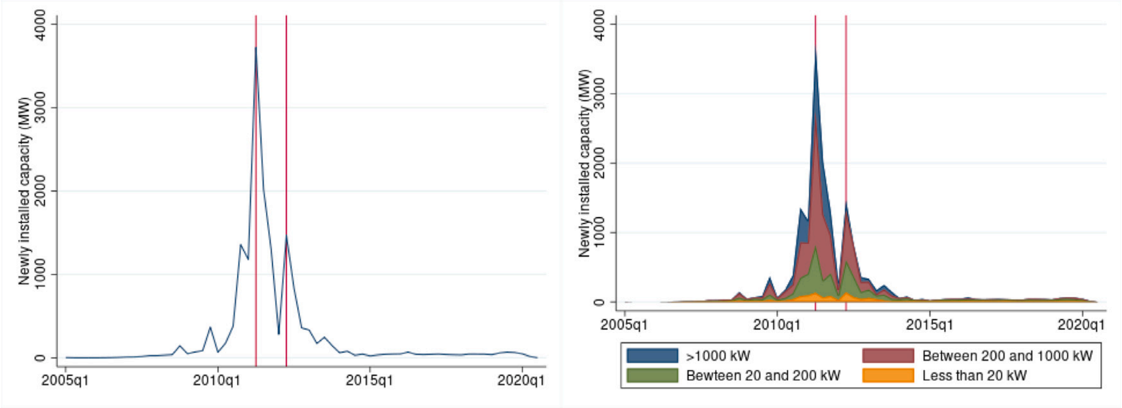


Fig. B.2. Diffusion of PV plants in Italy, overall and by class size. Notes: the two red lines are drawn in correspondence of the quarter prior to the start of the 4th (2011q2) and 5th (2012q2) *Conto Energia*. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
Source: Gestore Servizi Energetici.

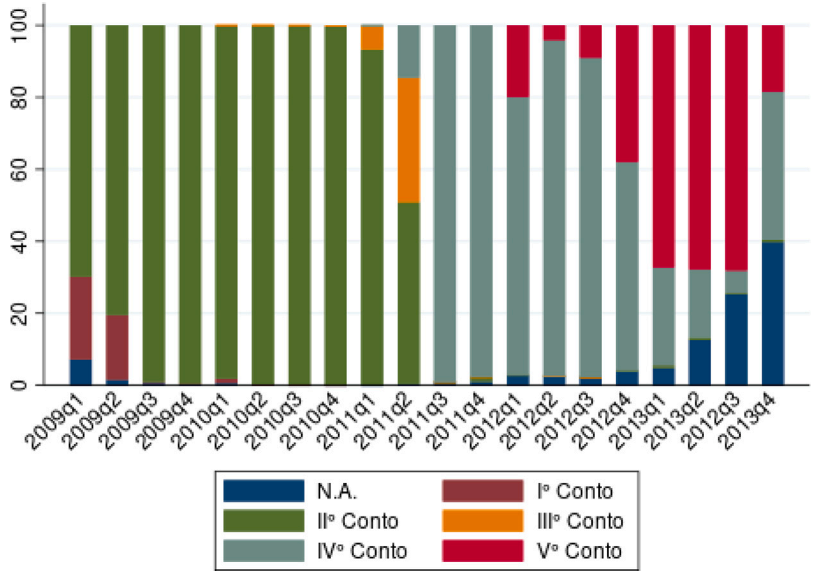


Fig. B.3. Distribution of newly installed plants across different rounds of Conto Energia. Notes: each bar represents the composition of total installed capacity in a given year and quarter according to the round of Conto Energia subsidising the underlying plants.
Source: Gestore Servizi Energetici.

these plants; given that the subsidy is higher for plants with capacity installed up to a given threshold, it is optimal for them to invest into a plant with size equal to the threshold and perceive the higher subsidy (Kleven, 2016). Starting with the production equilibrium, the capacity installed is:

$$K(A_i|I=1)=\begin{cases} A_i^{\sigma-1}\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}\widetilde{Y}\left(c-\overline{s}\right)^{-\sigma} & \text{if } A_i\le A^* \\ K^* & \text{if } A^*<A_i\le A^*+\Delta A^* \\ A_i^{\sigma-1}\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}\widetilde{Y}\left(c-\underline{s}\right)^{-\sigma} & \text{if } A_i> A^*+\Delta A^* \end{cases}$$

$$K(A_i|I=0)=A_i^{\sigma-1}\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}\widetilde{Y}p^{-\sigma} \tag{C.3}$$

And moving to profits:

$$\pi(A_i|I=1)=\begin{cases} \left(\frac{1}{\sigma-1}\right)A_i^{\sigma-1}\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}\widetilde{Y}\left(c-\overline{s}\right)^{1-\sigma} & \text{if } A_i\le A^* \\ \widetilde{Y}^{\frac{1}{\sigma}}\left(K^*A_i\right)^{\frac{\sigma-1}{\sigma}}-K^*\left(c-\overline{s}\right) & \text{if } A^*<A_i\le A^* \\ & \quad +\Delta A^* \\ \left(\frac{1}{\sigma-1}\right)A_i^{\sigma-1}\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}\widetilde{Y}\left(c-\underline{s}\right)^{1-\sigma} & \text{if } A_i> A^*+\Delta A^* \end{cases}$$

$$\pi(A_i|I=0)=\left(\frac{1}{\sigma-1}\right)A_i^{\sigma-1}\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}\widetilde{Y}p^{1-\sigma} \tag{C.4}$$

where A^* is the productivity level of a firm that chooses to invest in a plant of size K^* without bunching (from Eq. (C.3)):

$$A^*=\left(K^*\right)^{\frac{1}{\sigma-1}}\left(\frac{\sigma}{\sigma-1}\right)^{\frac{\sigma}{\sigma-1}}\widetilde{Y}^{-\frac{1}{\sigma-1}}\left(c-\overline{s}\right)^{\frac{\sigma}{\sigma-1}} \tag{C.5}$$

and $A+\varDelta A^*$ is the productivity level of a firm that is indifferent between investing in a plant of size K^* with bunching and investing in a plant of size $K^* + \varDelta K^I > K^*$ without bunching and therefore receiving the lower subsidy level (from Eq. (C.4))[29]:

$$\widetilde{Y}^{\frac{1}{\sigma}} \left(K^*(A^* + \varDelta A^*)\right)^{\frac{\sigma-1}{\sigma}} - K^* \left(c - \overline{s}\right) = \left(\frac{1}{\sigma - 1}\right)(A^* + \varDelta A^*)^{\sigma-1} \left(\frac{\sigma}{\sigma - 1}\right)^{-\sigma} \widetilde{Y} \left(c - \underline{s}\right)^{1-\sigma} \tag{C.6}$$

Moving to the investment decision, consider first the mass of firms with productivity $A_i \leq A^*$. In this region, there can be a region $A_i < A_1$ where firms decide not to invest conditional on $A_1 < A^*$. The greater the sunk cost for low capacity plants, the fewer firms with productivity $A_i \leq A^*$ choose to invest.[30] The investment decision for low productivity firms does not depend on $\overline{f}$, as these firms must pay a different sunk cost if they want to invest.

Next, consider the mass of firms with productivity $A^* < A_i \leq A^* + \varDelta A^*$. In this region, the not-investment equilibrium can only materialise in a neighbourhood of $A^* + \varDelta A^*$ (conditional on the sunk cost $\underline{f}$ being sufficiently high). Intuitively, as productivity grows, the difference between producing at constrained capacity when investing in a PV plant and producing at optimal capacity when buying energy in the market also grows so that it becomes increasingly less convenient to invest in a PV plant.[31] Therefore, the investment decision for intermediate productivity firms does not depend on $\overline{f}$, as these firms must pay a different sunk cost if they want to invest. Similarly, the extent of bunching, namely the mass of firms with productivity $A^* < A_i \leq A^* + \varDelta A^*$ choosing to invest, $B = \int_{A^*}^{A^*+\varDelta A^*} I(A)dG(A)$, does not depend on $\overline{f}$ either (see Fig. C.1). Finally, consider the mass of firms with productivity $A_i > A^* + \varDelta A^*$. In this region, there can be a region $A^* + \varDelta A^* < A_i < A_3$ where firms decide not to invest if the sunk cost $\overline{f}$ is high enough high (so that $A^* + \varDelta A^* < A_3$).[32] If the sunk cost is high enough so that $A^* + \varDelta A^* < A_3$, then a decline in the sunk cost will incentivise the entry of a greater number of firms as $\frac{\partial A_3}{\partial \overline{f}} > 0$. Furthermore, the positive impact is greater when the subsidy schedule, $s \in \left\{\underline{s}, \overline{s}\right\}$, is less generous, $\frac{\partial^2 A_3}{\partial \overline{f} \partial \underline{s}} < 0$, since in this case the relative importance of sunk costs for the value of the firm is greater.

Proposition 1. *As the sunk cost $\overline{f}$ declines:*

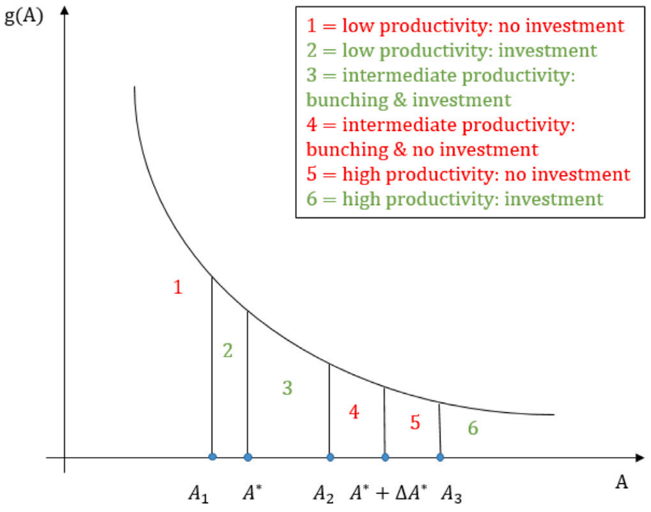


Fig. C.1. Investment regions based on firm productivity A.

1. *the number of firms investing in plants of size $K_i > K^*$ can either stay the same or increase, while the number of firms choosing to invest in plants of size $K_i \leq K^*$ is unaffected;*
2. *the extent of bunching is unaffected.*

The impact of the decline in the sunk cost $\overline{f}$ on the number of firms investing in plants of size $K_i > K^*$ when the subsidy schedule is less generous is larger or equal to the impact when the subsidy schedule is more generous.

C.2. Testing the presence of bunching and its response to the implementation of regional simplification reforms

To estimate the extent of bunching in a given region plant size distribution around the 20 kW threshold, we follow Kleven (2016). Specifically, we estimate the following regression, whose aim is essentially to fit the observed distribution through a suitable parametrisation in order to be later able to estimate the extent of bunching as the difference between the observed and the fitted distribution:

$$S_i = \sum_p \gamma_p \times i^p + \sum_{k=19}^{29} \delta_k \times I(k \leq i < k+1) + e_i \tag{C.7}$$

where $i = \{10, 10.1, \ldots, 20, 20.1, \ldots, 44.9\}$, S_i is the ratio between the number of plants with capacity installed $i \leq k < i + 0.1$ and the total number of plants, γ_p are a set of P coefficients for the pth-order polynomial of i, and δ_k are a set of $k \in \{19, \ldots, 29\}$ coefficients needed to account flexibly for the share of plants built in the bunching region. We chose to estimate Eq. (C.7) on a rescaled distribution (rescaled by the total number of plants) in order to make the coefficients comparable across regions and time frames.

The extent of bunching at the notch $K^* = 20$ kW is then equal to:

$$\widehat{B} = \widehat{S}_i - \sum_{k=19}^{29} \widehat{\delta}_k \times I(k \leq i < k+1)|_{i=19.9} \tag{C.8}$$

where $\widehat{B}$ identifies the extra-share (hence, 0.01 corresponds to one percentage point extra) of plants built with capacity $k = K^*$ beyond what would be predicted by the shape of the distribution around the threshold in the absence of bunching.

We estimate bunching according to Eq. (C.8) for each of the regions that implemented the regulatory simplification reforms using (1) all plants connected to the grid up to the quarter before the implementation of the reforms, (2) all plants connected to the grid up to nine months after the implementation of the reform. We calculate the

---

[29] Combining Eq. (C.5) and (C.6), the solution to $A^*+\varDelta A^*$ is given implicitly by:

$$\left(\frac{A^*}{A^* + \varDelta A^*}\right)^{(\sigma-1)\left(\frac{\sigma-1}{\sigma}\right)} \sigma - \left(\frac{A^*}{A^* + \varDelta A^*}\right)^{\sigma-1} (\sigma - 1) = \left(\frac{c - \overline{s}}{c - \underline{s}}\right)^{\sigma-1}.$$

[30] The productivity level of the firm that is indifferent between investing and not investing is $A_1 = \left[\frac{\underline{f}}{\left(\frac{1}{\sigma-1}\right)\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}\widetilde{Y}\left((c-\overline{s})^{1-\sigma}-p^{1-\sigma}\right)}\right]^{1/(\sigma-1)}$. By comparing this expression with Eq. (C.5), if the sunk cost $\underline{f}$ is sufficiently low, $\underline{f} < K^*\left(\frac{c-\overline{s}}{\sigma-1}\right)\left[1-\left(\frac{c-\overline{s}}{p}\right)^{\sigma-1}\right]$, then $A_1 < A^*$, and firms with productivity $A_i < A_1 < A^*$ will choose not to invest.

[31] The derivative of $\varDelta\pi(A_i) = \pi(A_i|I = 1) - \pi(A_i|I = 0)$ for $A^* \leq A_i < A^* + \varDelta A^*$ changes sign at most once. Since $\frac{\varDelta\pi(A_i)}{\partial A_i}|A^* > 0$, if the marginal buncher with productivity $A_i = A^* + \varDelta A^*$ chooses not to invest, then also firms with productivity $A_2 < A_i \leq A^* + \varDelta A^*$ choose not to, with A_2 being the productivity level of bunching firm that is indifferent between investing and not investing, implicitly defined by $\widetilde{Y}^{\frac{1}{\sigma}}\left(K^*A_2\right)^{\frac{\sigma-1}{\sigma}} - K^*\left(c-\overline{s}\right) - \underline{f} = \left(\frac{1}{\sigma-1}\right)A_2^{\sigma-1}\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}\widetilde{Y}p^{1-\sigma}$. Specifically, the marginal buncher chooses not to invest if the sunk cost is sufficiently high, $\underline{f} > \left(\frac{1}{\sigma-1}\right)(A^* + \varDelta A^*)^{\sigma-1}\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}\widetilde{Y}\left[\left((c-\underline{s})^{1-\sigma} - p\right)^{1-\sigma}\right]$.

[32] The productivity level of high productivity firm that is indifferent between investing and not investing is $A_3 = \left[\frac{\overline{f}}{\left(\frac{1}{\sigma-1}\right)\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}\widetilde{Y}\left((c-\underline{s})^{1-\sigma}-p^{1-\sigma}\right)}\right]^{1/(\sigma-1)}$.

standard errors both for the bunching coefficients and for after/before difference based on a bootstrap procedure with $N = 100$ replications.[33]

Appendix D. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.eneco.2023.106844.

References

Abashidze, N., Taylor, L., 2022. Utility-scale solar farms and agricultural land values. Land Econ. 98 (4).

Accetturo, A., Linarello, A., Petrella, A., 2017. Legal Enforcement and Global Value Chains: Micro-Evidence from Italian Manufacturing Firms. Bank of Italy Occasional Papers No. 397.

Antonelli, M., Desideri, U., 2014. Do feed-in tariffs drive PV cost or viceversa? Appl. Energy 135, 721–729.

Autor, D.H., Donohue, J.J., Schwab, S.J., 2006. The costs of wrongful-discharge laws. Rev. Econ. Stat. 88, 211–231.

Balta-Ozkan, N., Yildirimb, J., Connor, P.M., 2015. Regional distribution of photovoltaic deployment in the UK and its determinants: A spatial econometric approach. Energy Econ. 51, 417–429.

Barca, F., McCann, P., Rodriguez-Pose, A., 2012. The case for regional development intervention: place-based versus place-neutral approach. J. Reg. Sci. 52, 134–152.

Bloom, N., Bond, S., van Reenen, J., 2007. Uncertainty and investment dynamics. Rev. Econom. Stud. 74 (2).

Bollinger, B., Gillingham, K., 2012. Peer effects in the diffusion of solar photovoltaic panels. Mark. Sci. 31, 900–912.

Caneppele, S., Riccardi, M., Standridge, P., 2013. Green energy and black economy: mafia investments in the wind power sector in Italy. Crime Law Soc. Change 59, 319–339.

Cengiz, D., Dube, A., Lindner, A., Zipperer, B., 2019. The effect of minimum wages on low-wage jobs. Q. J. Econ. 134 (3), 1405—1454.

de Chaisemartin, C., D'Haultfoeuille, X., 2022. Two-Way Fixed Effects and Differences-in-Differences with Heterogeneous Treatment Effects: A Survey. NBER Working Paper No. 29691.

Clò, S., Cataldi, A., Zoppoli, P., 2015. The merit-order effect in the Italian power market: The impact of solar and wind generation on national wholesale electricity prices. Energy Policy 77, 79–88.

Clò, S., Fumagalli, E., 2019. The effect of price regulation on energy imbalances: a Difference in Differences design. Energy Econ. 81, 754–764.

Copiello, S., Grillenzoni, C., 2017. Solar photovoltaic energy and its spatial dependence. Energy Procedia 141, 86–90.

Deshpande, M., Li, Y., 2019. Who is screened out? Application costs and the targeting of disability programs. Am. Econ. J.: Econ. Policy 11 (4), 213–248.

Dharshing, S., 2017. Household dynamics of technology adoption: A spatial econometric analysis of residential solar photovoltaic (PV) systems in Germany. Energy Res. Soc. Sci. 23, 113–124.

Di Dio, V., Favuzza, S., La Cascia, D., Massaro, F., Zizzo, G., 2015. Critical assessment of support for the evolution of photovoltaics and feed-in tariff(s) in Italy. Sustain. Energy Technol. Assess. 9, 95–104.

ECOFYS, 2013. Design Features of Support Schemes for Renewable Electricity. Project number: DESNL13116, ECOFYS-EC (DG ENER).

ECORYS, Research and Consulting, 2010. Assessment of Non-Cost Barriers to Renewable Energy Growth in EU Member States - AEON. Rotterdam, 10th of 2010.

European Commission, 2020. Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Renewable Energy Progress Report.

Fadic, M., Garda, P., Pisu, M., 2019. The Effect of Public Sector Efficiency on Firm-Level Productivity Growth: The Italian Case. OECD Economics Department Working Papers No. 1573.

Gelabert, L., Labandeira, X., Linares, P., 2011. An ex-post analysis of the effect of renewables and cogeneration on Spanish electricity prices. Energy Econ. 33, S59–S65.

Germeshausen, R., 2018. Effects of Attribute-Based Regulation on Technology Adoption: The Case of Feed-in Tariffs for Solar Photovoltaic. Discussion Paper No. 18-057, Centre for European Economic Research (ZEW).

Giaccaria, S., Dalmazzone, S., 2012. Patterns of Induced Diffusion of Renewable Energy Capacity: The Role of Regulatory Design and Decentralization. Collegio Carlo Alberto Working paper No. 282.

Giacomelli, S., Menon, C., 2017. Does weak contract enforcement affect firm size? Evidence from the neighbour's court. J. Econ. Geogr. 17, 1251–1282.

Gibbons, S., 2015. Gone with the wind: Valuing the visual impacts of wind turbines through house prices. J. Environ. Econ. Manag. 72, 177–196.

Giordano, R., Lanau, S., Tommasino, P., Topalova, P., 2020. Does public sector inefficiency constrain firm productivity: Evidence from Italian provinces. Int. Tax Public Finance 27, 1019–1049.

Giordano, R., Tommasino, P., 2013. Public-sector efficiency and political culture. FinanzArchiv / Public Finance Anal. 69, 289–316.

Grembi, V., Nannicini, T., Troiano, U., 2016. Do fiscal rules matter? Am. Econ. J.: Appl. Econ. 8 (3), 1–30.

Helm, D., 2006. Regulatory reform, Capture and the Regulatory burden. Oxf. Rev. Econ. Policy 22, 169–185.

Hoen, B., Wiser, R., Thayer, M., Cappers, P., 2012. Residential photovoltaic energy systems in california: The effect on home sales prices. Contemp. Econ. Policy 31 (4), 708–718.

International Energy Agency, 2020. Projected Costs of Generating Electricity. International Energy Agency, Paris.

International Renewable Energy Agency, 2020. Renewable Power Generation Costs in 2019. International Renewable Energy Agency, Abu Dhabi.

Karteris, M., Papadopoulos, A., 2013. Legislative framework for photovoltaics in Greece: A review of the sector's development. Energy Policy 55, 296–304.

Keele, L., Lorch, S., Passarella, M., Small, D., Titiunik, R., 2017. An overview of geographically discontinuous treatment assignments with an application to children's health insurance. Adv. Econom. 38, 147–194.

Keele, L., Titiunik, R., 2015a. Geographic boundaries as regression discontinuities. Political Anal. 23, 127–155.

Keele, L., Titiunik, R., 2015b. Natural experiments based on geography. Political Sci. Res. Methods 1–31.

Kleven, H.J., 2016. Bunching. Annu. Rev. Econ. 8, 435–464.

Mazzanti, G., Santini, E., Zaccagnini Romito, D., 2012. Towards grid parity of solar energy in Italy: the payback time trend of photovoltaic plants during the last years. In: IEEE Power and Energy Society General Meeting.

Meyerhoff, J., Ohl, C., Hartje, V., 2010. Landscape externalities from onshore wind power. Energy Policy 38 (1), 82–92.

Monarca, U., Cassetta, E., Pozzic, C., Dileod, I., 2018. Tariff revisions and the impact of variability of solar irradiation on PV policy support: The case of Italy. Energy Policy 119, 307–316.

OECD, 2003. From Red Tape to Smart Tape: Administrative Simplification in OECD Countries. OECD Publishing, Paris.

O'Shaughnessy, E., Barbose, G., Wiser, R., 2020. Patience is a virtue: A data-driven analysis of rooftop solar PV permitting timelines in the United States. Energy Policy 144.

Owley, J., Morris, A.W., 2019. The new agriculture: From food farms to solar farms. Colum. J. Envtl. L. 409.

Parsons, G., Heintzelman, M.D., 2022. The effect of wind power projects on property values: A decade (2011–2021) of hedonic price analysis. Int. Rev. Environ. Resour. Econ. 16 (1), 93–170.

Qiu, Y., Wang, Y.D., Wang, J., 2017. Soak up the sun: Impact of solar energy systems on residential home values in Arizona. Energy Econ. 66, 328–336.

Roth, J., Sant'Anna, P.H., Bilinski, A., Poe, J., 2022. What's Trending in Difference-in-Differences? A Synthesis of the Recent Econometrics Literature. mimeo.

Scerrato, G., 2015. Solar PV feed-in Tariff: the distortion of Italian power market. In: XX Summer School Francesco Turco - Industrial Systems Engineering.

Schaffer, A.J., Brun, S., 2015. Beyond the sun—Socioeconomic drivers of the adoption of small-scale photovoltaic installations in Germany. Energy Res. Soc. Sci. 10, 220–227.

Terna, 2020. Pubblicazioni statistiche. https://www.terna.it/it/sistema-elettrico/statistiche/pubblicazioni-statistiche.

Vannutelli, S., 2022. From Lapdogs to Watchdogs: Random Auditor Assignment and Municipal Fiscal Performance. mimeo.

Voigt, C.C., Straka, T.M., Fritze, M., 2019. Producing wind energy at the cost of biodiversity: a stakeholder view on a green-green dilemma. J. Renew. Sustain. Energy 11.

Wanga, Y., Suna, X., Guob, X., 2019. Environmental regulation and green productivity growth: Empirical evidence on the Porter Hypothesis from OECD industrial sectors. Energy Policy 132, 611–619.

---

[33] Specifically, after having estimated Eq. (C.7) for a given region/period (either before or after the reform), we save separately the fitted values and the residuals. Then, for each replication, we randomly sample with replacement the residuals, sum them to the fitted values and construct a new plant size distribution, on which we re-run the bunching estimation Eqs. (C.7)–(C.8). At each replication, we save $\hat{B}^i$. We then use the distribution of thus constructed $\hat{B}^i$, with $i = 1, 2, \ldots, 100$ to calculate standard errors and confidence intervals for the bunching estimate.