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JEL Classification: C23, D72, H23, Q48

Keywords: financing climate policy, photovoltaic systems, retrospective voting, buying votes

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We analyze the political impact of a generous solar panel subsidization program. Subsidies far exceeded their social benefit and were partly financed by new taxes to adopters and by electricity surcharges to all consumers. We use local panel data from Belgium and find a decrease in votes for government parties in municipalities with high adoption rates. This shows that the voters' punishment for a costly policy exceeded a potential reward by adopters who received the generous subsidies. Further analysis indicates that punishment mainly comes from non-adopters, who change their vote towards anti-establishment parties.

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1 Introduction

There is now a broad consensus among scientists that the massive increase in CO_2 emissions has been responsible for the climate change observed over the past decades. There is also a growing awareness that drastic policies are required to reduce CO_2 emissions and prevent a further acceleration of global warming in the future.

However, there is much less consensus on the type of policies that are required to reduce CO_2 emissions. Economists often favor Pigouvian taxes on CO_2 emissions to correct for the externalities.[1] Yet, several authors argue that both the design and the implementation of such taxes might be politically complicated for a variety of reasons: distributional concerns, industry pressure, aversion to taxes, lack of coordination, or fiscal competition between countries (Marron and Toder, 2014; Jenkins, 2014; Dolphin *et al.*, 2020). As a result, politicians have often favored a variety of subsidy programs to promote renewable energy sources (RES), such as solar, wind or biofuel. This, in turn, has led to wide ranging costs for technologies and interventions that aim to reduce CO_2 emissions; see Gillingham and Stock (2018) for a review of evidence from economic studies.

Despite the political arguments behind the choice for technology-specific subsidies, there is little evidence on their electoral impact. In this paper, we aim to fill this gap in the literature by looking at the impact of subsidies for solar photovoltaic systems (PV) on votes for the parties that introduced them.

PV is one of the green technologies that received the largest support in many countries. The California Solar Initiative (Hugues and Podolefsky, 2015) and the German feed-in-tariff are the most prominent examples. The solar subsidy programs often combined different support measures, including feed-in-tariffs, green certificates, capital subsidies, tax credit and net metering.[2] In many countries, the support provided to solar energy was considerable, especially for small-scale photovoltaic systems installed by the households on their rooftop. For Germany, Marcantonini and Ellerman (2015) estimate the support corresponds to an implicit carbon price for solar energy of 552€per ton for the period 2006-2010, far above the perceived optimal carbon

[1] See, for example, the Economists' Statement on Carbon Dividends (https://clcouncil.org/economists-statement), written in January 2019, and signed by 27 Nobel laureates and 15 former chairs of the US Council of Economic Advisers.

[2] Campoccia *et al.* (2009), Dusonchet and Telaretti (2010, 2015) detail the main instruments used in several EU countries and estimate their relative importance by calculating the financial return of an investment in a small-scale (residential) PV installations. Rodrigues *et al.* (2016) also includes non-EU countries in their comparisons.

price.[3] Therefore, the high support creates a group of PV adopters that benefit from the policy, while also creating a cost for the rest of society that likely outweighs the social gains.

For our analysis, we exploit the generous subsidy programs for residential solar photovoltaic systems in Belgium. Starting in Flanders in 2006, each of the country's three regions (Flanders, Wallonia and Brussels) offered subsidies for residential solar installations. The programs combined production subsidies in the form of tradable green certificates and net metering[4] with investment subsidies at the moment of the installation. The subsidies were initially very generous and adoption by the households was massive. To give a comparison, at the end of 2012, the cumulated PV power in Germany, a leading country in solar production, accounted for 32,389 MW but small-scale residential installations (<10kW) represented only 9% of the installed capacity (4,370 MW).[5] In Belgium, small scale installations accounted for 1,550 MW in 2012. The installed power by households was 0.05 kW per capita in Germany and 0.14 kW in Belgium.

The combination of high subsidies and high adoption created both a financial and a political problem. Subsidies were mainly linked to the solar production and they were granted for a long period (up to 20 years). As a result, governments created a solar debt as they committed to pay a large amount of subsidies to PV adopters. We estimate that the total amount of production subsidies promised to solar during the 2006-2016 period amounted to 9.19 billion €, or 811 €/capita. This corresponds to a subsidy of 303 €/MWh or an implicit carbon price of 671 €/ton CO_2.[6] This clearly indicates that Belgium overshot its support to solar PV.

The funding of this solar debt soon became a critical political issue. It is well documented that PV adoption is increasing with income (De Groote *et al.*, 2016) and funding solar subsidies through surcharges on the electricity bill could be regressive (Feger *et al.* 2021, Winter and Schlesewsky 2019). The financing of these costs and the associated redistributive aspects were one of the most important and contentious debates during the last years, both in Flanders and in Wallonia.

To cover the cost of the rapidly increasing solar debt, the regional governments introduced a dedicated surcharge on the electricity bill. In addition, the regions decided to tax the adopters

[3] To give an idea, Nordhaus (2014) estimates a social cost of carbon equal to $22.1 (in 2005 $) per ton of CO_2 for the year 2020. In Europe, the carbon price on the EU ECTS markets was close to this number but recently increased up to almost 100€ by the start of 2022, which is also more in line with recent estimates, see e.g. Carleton and Greenstone (2021) who estimate a social cost of carbon for 2020 of $125.

[4] With net metering, solar production is valued at the electricity retail rate (Brown and Sappington, 2017 ; Gautier *et al.*, 2018).

[5] Data from Germany are retrieved from Prol (2018).

[6] Assuming solar production replaces production by gas power plants, emitting 450 grams of CO_2/MWh.

for their role as "prosumers", i.e. electricity consumers who installed a solar PV and receive payments for the electricity they produce. While adoption was large in most of the country, the extent to which the costs were spread out over time differs greatly between the regions, leading to substantial variation in electricity prices in recent years.

Regional governments are appointed for a term of five years after the regional election. The main policies were designed during the legislation of 2004-2009, which at that time were center or center-left coalitions in the three regions. Our objective is to investigate whether and how technology adopters and non-adopters modified their vote to reward or punish the politicians who designed these programs.

We consider two hypotheses. A first hypothesis is that voters who benefited from the subsidies reward the government that initially designed the subsidy scheme by voting for the responsible parties. This "buying votes" hypothesis, according to which governments will implement certain policies to buy votes from beneficiaries, was first introduced by Biais and Perotti (2002). Following their idea, Ovaere and Proost (2015) propose a political economy model where candidates buy the citizens' votes by offering generous subsidies for solar PVs. Their model explains why politicians prefer inefficiently high subsidies for solar relative to wind because the solar subsidies are paid to households (voters) while wind subsidies are paid to firms. According to this hypothesis, adopters and prospective adopters will vote for the incumbent parties to maintain the high return on solar installation and to reward the parties for their policy. We should therefore observe a positive effect on votes.

A second hypothesis is retrospective voting. Accordingly, citizens use their vote to discipline politicians, rewarding on ballots those who performed well and punishing those who did not. Retrospective voting may apply to both non-adopters and adopters of PVs. On the one hand, the non-adopters, who did not benefit from the subsidies punish the government when it becomes apparent that they end up paying a high subsidy cost for only limited (environmental) benefits. On the other hand, the adopters themselves may also punish the government if they see that some of their benefits are taken away by the imposition of new fees that reduce their return on investment.

Our setting is particularly suitable to investigate how voters hold politicians accountable. First, information on policies needs to adjust the priors voters have about policy makers (Arias et al. 2022). At the time, climate policy was new, suggesting voters likely did not have strong priors on the ability of the incumbents to do it well.[7] Second, the policy impact needs to be salient

[7] The Kyoto protocol was formally adopted by the EU in 2002 and came into force in 2004. This was the start of

(Chetty et al. 2009, Huet-Vaughn 2019). Investments in rooftop solar by households are very visible where people reside, and adoption rates were high. At the municipality-level, they average 10% and can go up to 29%. The policies also received large attention in the media and the financial details further enforce the salience. All electricity consumers were regularly reminded about the costs because of surcharges for green energy that appeared on their electricity bills. Adopters were regularly reminded of the benefits as most of the subsidy was paid out by a government agency, each time a certain level of electricity production was reached.

To evaluate these hypotheses, we exploit local municipality-level variation in the solar PV adoption rate across the country. We specify a model for the election outcomes of the incumbent parties (i.e. the center or center-left parties that designed the programs) at the local level during the regional election years 2009, 2014 and 2019, in comparison with the pre-program election years 1995, 1999 and 2004. We ask whether the election outcomes were more or less favorable to the incumbent parties in those municipalities where solar PV adoption had been higher. We allow for fixed effects for each municipality and each election. Our model can therefore be interpreted as a difference-in-differences framework with the local adoption rate measuring the treatment intensity. We show the robustness of our results by also allowing for changes in votes that can be explained by a large set of local demographics, including home ownership rates and income. We also test the common trend assumption using the pre-program election years.

Our main finding is that the incumbent parties received *fewer* votes in municipalities where PV adoption has been more successful. This is inconsistent with the buying votes hypothesis, according to which voters reward the incumbent parties. Instead, our finding is consistent with our alternative hypothesis of retrospective voting. Voters punish the incumbent parties, once it became apparent that the financing costs would be high and be paid to a large extent by non-beneficiaries.[8] We also find that the punishment tends to be more severe in Flanders and grows over time, consistent with the periods and regions in which more costs were passed on to consumers through substantially higher electricity prices and to adopters through a dedicated prosumer fee.

Under retrospective voting, both non-adopters and adopters may lie at the basis of pun-

several policies and debates at the regional and national level.

[8]Furthermore, the costs and benefits for non-adopters and adopters might not be correctly perceived by the citizens. In Douenne and Fabre (2022), it is shown that most of the respondent to their survey have pessimistic beliefs regarding the redistributive aspects of the carbon tax. Pessimistic beliefs may exacerbate the voters' response to the policy.

ishing the government. To distinguish between both groups, we add the share of PV adoption in neighboring municipalities to our model of election outcomes. We find an effect that is at least as negative as for the share of PV adoption in the municipality itself. Hence, punishment appears to be mainly driven by adopters' neighbors, i.e. the non-adopters.

Finally, using the same methodology, we consider which political parties were most affected. Among the incumbent parties, mainly the socialist parties were negatively affected. This is intuitive as they were part of government and most associated with the subsidy policies in the public debate. Moreover, their voters are expected to attach more weight to the issue of subsidies going to more wealthy households. We cannot exclude the possibility that other government parties lost votes too. The parties that gained votes were the parties on the most extreme sides of the political spectrum (both on the left and the right). As they were never in government, it could point to voters attaching blame on all (traditional) parties. An alternative explanation is that it could reflect an increased anti-establishment sentiment following from a failed policy. Similarly, but in a different context, Sartre *et al.* (2020) show that the populist vote for both the extreme right and the extreme left is on the rise in the French municipalities that contracted toxic loans before the financial crisis.

Related literature We contribute to three strands of literature. A first strand investigates the impact of solar panel policies on household behavior. Hughes and Podolefsky (2015) focus on the impact of investment subsidies on adoption in California. Matisoff and Johnson (2017) and Gautier and Jacqmin (2020) focus on the role of net metering policies. Crago and Chernyakhovskiy (2016) show that investment subsidies have relatively more impact than factors affecting future benefits like energy prices or solar irradiation. De Groote and Verboven (2019) show that households discount the future benefits heavily and confirm that investment subsidies are more effective than production subsidies to promote PV adoption. Feger *et al.* (2021) investigate optimal subsidy and tariff design in terms of efficiency and equity and Langer and Lemoine (2018) investigate the optimal timing. We contribute to this literature by investigating the electoral impact of solar panel policies. Closest to our work is Comin and Rode (2013). They do not focus on incumbent parties, but instead show that PV adopters vote more for the green party because of increased awareness of environmental issues.

A second strand of literature discusses the impact of green energy policy on voting behavior.[9]

[9]Another literature in political economy discusses the impact of lobbying. For instance, Aidt (1998) studies the structure of environmental taxes under lobbying and Jenner *et al.* (2013) show that energy producers from conventional sources are actively and successfully lobbying against subsidies for energy from renewable sources.

We distinguish between two mechanisms: "buying votes" and "retrospective voting".

In their seminal paper, Biais and Perotti (2002) show that a government may provide inefficiently high support for investment by citizens-voters to give them a stake in the policy and thereby change their political preferences. Citizens are then more likely to support pro-investment parties because they have invested and obtained a private interest in pro-investment policies. While this paper was applied to privatization, several papers have applied this "buying votes" idea to environmental policies. By providing high subsidies for a pro-environmental policy, citizens or firms are taking part in the ecological transition and they are more likely to support a pro-environmental policy (Urpelainen, 2012 ; Alkin and Urpelainen, 2013). Ovaere and Proost (2015) propose a model to explain why politicians prefer solar over wind subsidies to buy votes. Pani and Perroni (2018) show that politicians have incentives to maintain inefficiently high energy subsidies instead of phasing them out to secure their re-election.

While most of the literature on retrospective voting has focused on general economic performance[10] (GDP growth, employment, etc.), a recent literature considers the impact of environmental policies both at the national (Obradovich, 2017) and at the local level (for instance the policy response to a natural disaster as in Neugart and Rode (2021)). These later studies build upon the fact that the costs and benefits of environmental policies are not equally spread across the territory. Stockes (2017) considers the example of wind turbines. While in terms of climate they benefit all, the residents living close to the windmills may suffer additional costs because of their proximity. Using data from Ontario (Canada), he identifies a loss for the incumbent party/candidate from voters located at a short distance from the mills (up to 3km). On the contrary, Umit and Schaeffer (2020) do not find a significant effect in Switzerland.

Even with substantial costs, environmental policies can receive public support. An important example is Germany's nuclear phase-out. The antinuclear sentiment after the Fukushima disaster led to the support of a large majority of the population (Goebel *et al.*, 2015), even though social costs largely outweigh the benefits (Jarvis *et al.*, 2022). Similarly, a pro-solar sentiment could prevent voters from punishing politicians.

We contribute to this literature by empirically investigating the impact of green technology subsidies on votes in a setting where the theoretical impact is ambiguous as voters have reasons to both reward and punish the government.

Finally, we contribute to the recent and growing empirical political economy literature to evaluate the impact of spending on voting behavior. Several papers look at the impact on votes

[10] See Healy and Malhotra (2013) for a survey.

by beneficiaries of cash transfers in developing countries. For example, Labonne (2013) exploits the variation created by the gradual roll-out of the program. Manacorda *et al.* (2011) make use of a discontinuity in the assignment rule. Recent literature has also looked at the impact of spending in developed countries using quasi-experimental variation. Compared to cash transfers, these policies are often more difficult to assign to a specific group or area. Therefore, researchers resort to a measure of treatment intensity to investigate their effect. Acemoglu *et al.* (2021) show how voters rewarded the Labor Party in Norway for national schooling reforms by exploiting local differences in the intensity of the policy. Huet-Vaughn (2019) finds positive effects on votes for the US democratic party in areas where investments in public goods were more salient. We adopt a similar strategy by exploiting the local salience of the policy, measured by the PV adoption rate. In contrast to these papers, we show that voters are able to look beyond the initial impact of increased spending and punish governments for policies of which the costs outweigh the social gains.

The rest of this paper is structured as follows. Section 2 discusses the subsidy programs and how they influenced the investment benefits and the public debt. Section 3 discusses how the debt was financed. Section 4 describes our empirical approach and results and Section 5 concludes.

2 Subsidy programs to promote residential PV installations

2.1 The green certificate mechanisms

Belgium is a federal state composed of three regions: Flanders, Wallonia and Brussels. The promotion of green energy is a regional responsibility. Since 2003 each region implemented a system of green certificates (GC) to support renewable energy sources (RES), such as wind, solar and biomass. The green certificates are production subsidies. They are awarded for a given period for each MWh produced from a certified renewable energy source. At the same time, the energy retailers have to meet quota obligations: a given percentage of their sales, fixed annually, should come from green energy sources. To meet their quota obligations, the retailers can buy certificates from producers on dedicated GC markets and they can pass through the cost of these obligations to end-consumers.

The grid operator is the designated default buyer and it has the obligation to buy all the certificates from any green producer that asks to do so at a minimum guaranteed price.[11] The

[11] The major difference between the GC mechanism in Flanders and Wallonia is that the minimum guaranteed

cost associated with this obligation is financed by a dedicated surcharge on the grid tariff paid by the consumers, but the pass-through is not automatic.

2.2 Specific subsidies to solar energy for residential installations

Starting in 2006, the regions wanted to encourage the installation of small-scale PV on the rooftop by the households, which were not profitable under the GC mechanisms in place. Interestingly, the regions distinguish residential and commercial solar installations, the former receiving much higher support. A residential installation is made by a household on his rooftop and there is a power limit of 10 kWp to be eligible.

Flanders was the first region to have a dedicated program for residential solar PV installations in 2006, Brussels and Wallonia followed in 2007 and 2008. These initially very generous programs remained in place until 2012 in Flanders and 2014 in Wallonia, when major reforms took place.

In the three regions, the solar programs combined the same three subsidy types: green certificates, net metering and investment subsidies. But the timing and the magnitudes of the subsidies differ between regions. In Figure 1, we represent the subsidy provided by these three instruments for each region together with the module prices for the period 2006-2016.[12]

2.2.1 The green certificate mechanism for solar energy

To boost the support, the green certificate subsidy was considerably increased above the amount of the general green certificate system described in Section 2.1. In Flanders, this was done by increasing the minimum guaranteed price for the solar producers, with the obligation for the grid operator to cover the difference between the guaranteed price and the market price. In Wallonia and Brussels, the increase was implemented by giving more GC per MWh produced, with the obligation for the grid operator to buy all the GC in excess supply on the market at the floor price. In both Flanders and Wallonia, the granting period was also extended.

At the start of the program, solar producers in Wallonia received 7GC per MWh produced for 15 years, compared with 1GC during 10 years for wind. With a trading price of 88€ per GC

price is technology-specific in Flanders while it is uniform in Wallonia.

[12]Partial information on subsidy programs in Belgium is available in De Groote et al. (2016) and De Groote and Verboven (2019) for Flanders from 2006 to 2012 and in Boccard and Gautier (2015, 2020) for Wallonia from 2008 to 2014. The present paper completes these earlier studies by providing a comprehensive description of the programs in the three regions and estimates of the corresponding NPV. The detailed computation and data sources are provided in Appendix A.

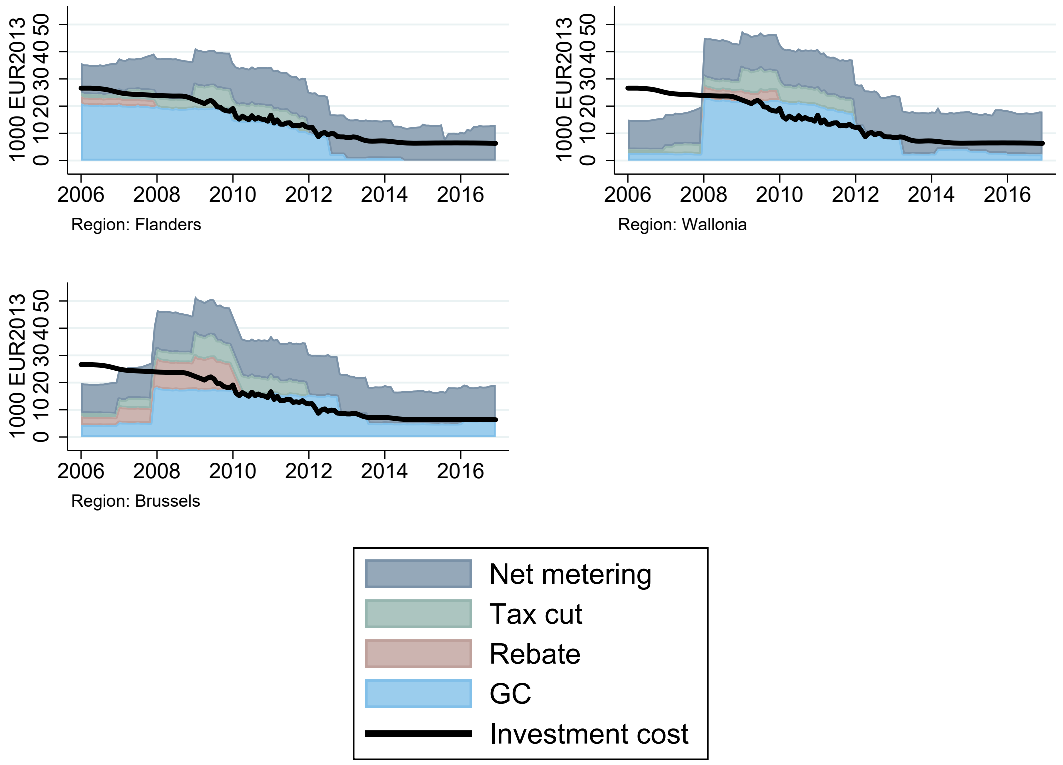

Figure 1: Total subsidies of a 4kWp installation in each region, 2006-2016

Notes: Each graph refers to one region (Flanders, Wallonia, Brussels) during 2006-2016. It shows the annual evolution of the investment cost, i.e. module price, of a 4kWp installation (black line) and the present value of the associated financial benefits from the green certificates (blue area), net metering (gray area), tax cuts (green area) and rebates (pink area). The amounts are expressed in 1000 Euro, adjusted for inflation (in 2013 prices). The present values are computed based on the lifetime of the solar PV, duration of the financial benefits, and an interest rate of 3%, see Appendix A for details.

in 2008, the subsidy accounted for 616€ per solar MWh. In Flanders, solar producers received 1GC per MWh for 20 years with a guaranteed price of 450€, compared with 1GC during 10 years with a guaranteed price of 80€ for wind.

The subsidies were left unchanged from 2006 to 2009 in Flanders and from 2008 to 2012 in Wallonia, despite rapidly changing market conditions with decreasing module prices.[13] There was no automatic adjustment mechanism[14] and the adaptations should be made by the regional governments who took time before making decisions. As a consequence, the generous initial support combined with rapidly declining module prices made the investment in solar PV ex-

[13]Flanders reduced the guaranteed price from 450€ to 350€ in 2010; Wallonia reduced the granting period to 10 years at the end of 2011. Further adaptations were made afterward.

[14]As it was for instance the case in Germany where the government introduced in 2009 an automatic adjustment mechanism for its feed-in-tariff (Grau, 2014).

tremely profitable, generating massive adoption and a high cost for society, as we document hereafter.

The system of GCs was profoundly reformed in 2013 (Flanders) and 2014 (Wallonia) to be more flexible and better adapt to the market conditions. Instead of committing to a mechanism, governments commit to a rate of return and adjust their support accordingly. As a result, subsidies were gradually phased out. GCs are no longer offered to residential PV installations since July 2014 in Flanders, and since July 2018 in Wallonia. Nowadays, only the region of Brussels continues to offer GCs for solar installations.

2.2.2 Net metering

In addition, households benefited from net metering. In Belgium, most of the meters were mechanical and the PV inverter is connected to the existing meter. When the solar production exceeds the consumption, the electricity surplus is exported to the grid, so that the meter runs *backward*. When the consumption exceeds the solar production, electricity is imported from the grid, and the meter runs *forward*. The meter then records the household's net consumption (consumption minus solar production) and this recording is used for the yearly billing.[15] With net metering, the energy produced by the solar installation is valued at the retail price. This includes not only the electricity price but also all extra charges for distribution and taxes so that a household's benefit from the generated electricity exceeds the market price of generating electricity. This benefit is particularly important because the tariff structure is essentially volumetric, i.e. based on the recorded consumption in kWh, with no or small fixed fees. This means that a prosumer who has a solar production equivalent to his/her yearly consumption has an electricity bill close to zero.

2.2.3 Investment premium and tax cuts

Finally, at the start of the programs, all regions offered rebates, specified as a percentage of the PV investment with a cap. In addition, for the years 2006-2011, the federal government supported investments in energy-saving technologies, including solar panels, by granting a tax credit.

[15] If the solar production exceeds the consumption on a yearly basis, a zero consumption is used for the billing.

2.3 Net present value and PV adoption

The subsidy schemes in the three regions provided huge support to residential PV installations (Figure 2) and as a result PV adoption was massive (Figure 3). Figure 2 reports our estimates of the net present value (NPV) of a 4kWp installation in Flanders, Wallonia and Brussels for the period January 2006-December 2016.

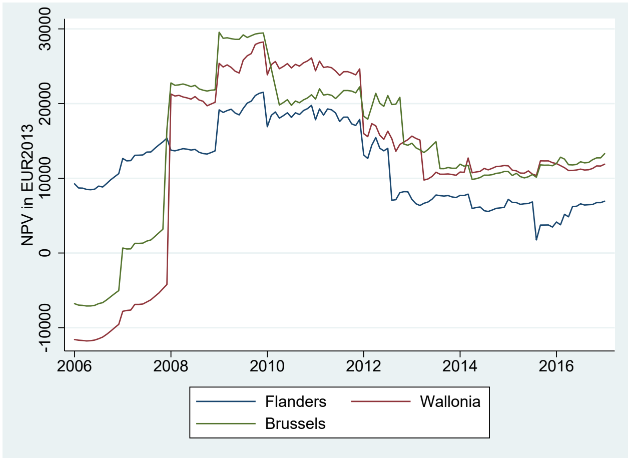

Figure 2: Net present value of a 4kWp installation in each region, 2006-2016

Notes: This graph shows the annual evolution of the net present value of a 4kWp installation, i.e. the difference between investment costs and the present value of total financial benefits. The amounts are expressed in 1000 Euro, adjusted for inflation (in 2013 prices). The present values are computed based on the lifetime of the solar PV, the duration of the financial benefits, and an interest rate of 3% (as in Figure 1).

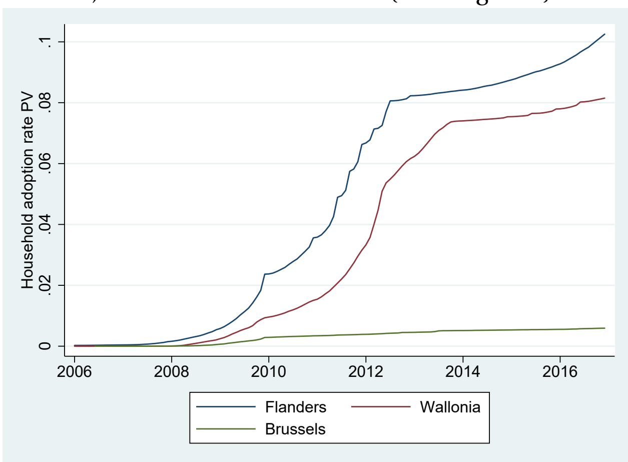

Figure 3: Cumulative adoption rate in each region, 2006-2016

Notes: This graph shows the annual evolution of the total adoption rate, i.e. the cumulative number of all PV installations per household.

Figure 3 shows the evolution of the total adoption rate, i.e. the cumulative number of PV installations divided by the number of households.[16] The total adoption rate has grown sharply

[16]Throughout this paper, we make use of data from the Census of 2011 (https://census2011.fgov.be/)

in both Flanders and Wallonia, while it remained limited in urban Brussels. Wallonia started slightly later than Flanders, as may be expected because it introduced the programs at a later point. New adoptions were especially high during 2009-2012 when the NPV of investment reached the highest levels. At the end of 2012, 8% of the Flemish households and 6% of the Walloon households were prosumers. After that, the reforms decreased the NPV and the rate of investment correspondingly dropped.

2.4 The cost of subsidies

The combination of generous subsidies and high adoption generated a huge cost for society. Production subsidies that have to be paid for a long period (up to 20 years in Flanders) created a green certificate debt. Furthermore, net metering resulted in a lost income for grid operators who need to be compensated. Only the investment and tax subsidies that were paid from the general budget, did not create any long term financing problems.

We summarize the evolution of this debt in two figures. Figure 4 shows the present value of the commitments made to new adopters between 2006 and 2016. Figure 5 shows the yearly flow of payments to adopters between 2006 and 2036, based on these commitments and assuming no new commitments.

2.4.1 The green certificate debt

The main cost overrun came from the cost of the GC mechanism. GCs are granted for a given period and linked to solar production. Consequently, governments committed to paying high subsidies for a long time, creating a *green certificate debt.* This debt corresponds to the value of production subsidies, under the form of GCs that the government *committed* to pay during the granting period of the certificates and that will be passed through to consumers.

Figure 4 shows the evolution of the net present value of new commitments since the start of the program in 2006. In the peak year 2011 the present value of new GC commitments to those who installed a PV system during that year represented more than 400€ per household in both Flanders and Wallonia. This cost will be spread over the subsequent granting period. This is evident from Figure 5, which shows that the annual payments reached the peak amount of 100€ per household in Flanders in 2011, and 140€ in Wallonia one year later. Payments remain

to obtain demographic information (at the municipality level). The data on adoptions were provided by regional government agencies: Brugel (Brussels), CWAPE (Wallonia) and VEA (Flanders).

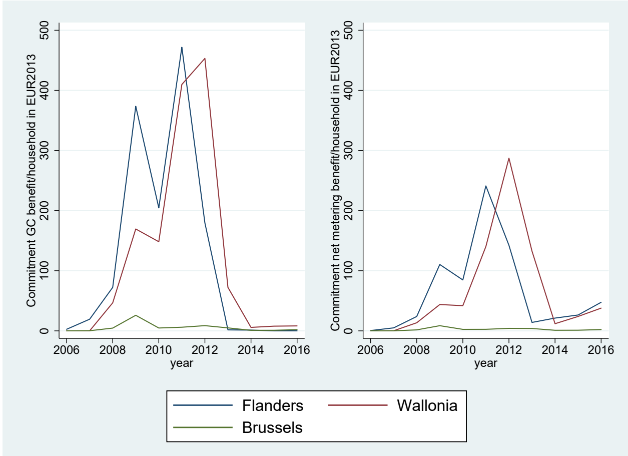

Figure 4: Present value of commitments to new adopters in each region, 2006-2016

Notes: This graph shows the annual evolution of the present value of commitments to new adopters, stemming from green certificates (left panel) and net metering (right panel). The amounts are expressed in Euro per household, adjusted for inflation (in 2013 prices).

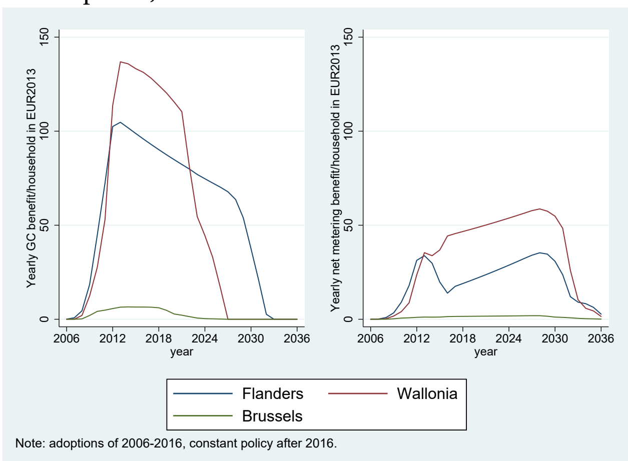

Figure 5: Flow of payments to all adopters in each region, 2006-2016

Notes: This graph shows the annual evolution of the payment flow to eligible past adopters, stemming from green certificates (left panel) and net metering (right panel). The amounts are expressed in Euro per household, adjusted for inflation (in 2013 prices).

high in subsequent years, even though new commitments had stopped: they extend up to 2027 in Wallonia and 2034 in Flanders.

2.4.2 The cost of net metering

With net metering, imports from the grid and exports to the grid are both valued at the electricity retail price. The retail price is the sum of three components: the commodity price paid to retailers, the grid tariff and the different taxes and surcharges.

To estimate the subsidy from net metering, we consider a net billing counterfactual (Gautier *et al.*, 2018) where the electricity imports are valued at the retail price but the exports are valued at the commodity price. We consider that a prosumer self-consumes 35% of his/her solar production.[17] The subsidy from net metering can then be computed as:

$$\text{Subsidy} = (\text{solar production in MWh}) \times (1\text{-}0.35) \times (\text{retail price - electricity price})$$

which is the lost income of the DSOs.

Figures 4 and 5 report the present value and the yearly payments corresponding to the subsidy from net metering. The figures show that this component is non-negligible but smaller than the GC benefits. Nevertheless, its importance is rising in recent years.

Overall, the total amount of subsidies provided together by the GC and the net metering during the period 2006-2016 is equal to 9.19 billion€ for an expected solar production equal to 30.34 million MWh or a subsidy of 302.83 €/MWh (see Table 1 for detailed numbers per region).

	Flanders	Wallonia	Brussels	Total
Total subsidy (in billion EUR2013)	5.846	3.290	0.051	9.187
Expected production (in million MWh)	19.910	10.271	0.157	30.338
Subsidy EUR2013/MWh	293.63	320.36	322.81	302.83

Table 1: Total subsidy costs per region, 2006-2016

Notes: The first row of this table shows the total subsidy costs over 2006-2016, i.e. the present value of all commitments to adopters, covering both green certificates and net metering (from Figure 4) and discounted/compounded to 2013 using a yearly discount factor of 0.97. The amounts are expressed in billion euros, adjusted for inflation (in 2013 prices). The second row shows the expected production, in million MWh, and the third row the implied subsidy per MWh.

3 Financing solar subsidies

The generous subsidies and the massive PV adoption implied substantial and increasing financial costs to society. This high take-up rate and the corresponding high total subsidies to be paid were largely unanticipated by the governments in charge.[18] Furthermore, there was no cap on

[17]A similar rate is used by the Belgian regulators to compute the profitability of a representative PV installation. Self-consumption depends on the consumption profile, the installation size and the incentives. Empirical estimations show a lot of variation in self-consumption rate across consumers and countries (McKenna *et al.*, 2019). Lang *et al.* (2016) estimate an average self-consumption of 40% for small residential buildings and McKenna (2018) an average of 45% for UK households with PV.

[18]In Flanders, the bill that introduced the policy stated an expected total capacity of 16,500 kWP by 2010 (Source: Flemish Parliament, piece 2188 (2003-2004)). By the end of 2009, and only looking at PVs <10kW, total capacity had

the eligible solar capacity. Around 2012, it became apparent that the GC mechanism was extremely costly and that this cost would be passed through to consumers. This has subsequently led to an intense political debate, and subsidies to solar PVs became a political issue.

There were two main controversies in the political debate. First, there was a debate on the magnitude of the GC subsidies, which were considered too generous, and needed to be revised downwards several times. The prosumers who had adopted in the most generous years (up to 2012) had received very important windfall profits, and there was an increasing awareness that these would eventually have to be paid by the electricity consumers. Second, there was a debate on the allocation of the cost of the subsidies to the different categories of consumers as it created important redistributional issues.

3.1 Financing and reducing the GC debt

The reforms of 2013 (Flanders) and 2014 (Wallonia) aimed at reducing the generosity of the subsidy mechanism and keeping the costs under control. The mechanism became more flexible to more closely follow the market conditions and limit the subsidies paid. In addition, governments had the responsibility to find a solution to finance the GC debt.

To finance the debt, the regions imposed additional surcharges on the electricity bill but the two main regions adopted different solutions. In Flanders, the debt burden was shared more or less equally among all the households. In Wallonia, traditional consumers paid the largest share as the additional surcharges were volumetric (in €/kWh). But the region also reduced the debt by modifying the GC mechanism ex-post, thereby reducing the return on investment for solar installations. Furthermore, part of the debt was frozen and planned to be paid later by future consumers.

3.1.1 Flanders

In 2015, the Flemish government imposed what was essentially a flat tax on each electricity household. The amount of the tax increased with the level of consumption, but only to a small extent, which was the main critique in the public debate. The tax was substantial. Consumers

already reached 260,398 kWp (15 times higher than the initial estimate). By the end of 2012, the end of the first phase of the GC policy, it had reached 1,046,164 kWp (63 times higher). Similarly in Wallonia, the energy regulator had in 2007, a forecast of 12,000 solar installations for the period 2008-2012 with a cumulated power of 41 MW. At the end of 2012, there were 98,000 installations in Wallonia (8 times mores) with a cumulated power of 556 MW (13 times more) (Source: CWAPE, 2007 and 2012, Annual report on green certificates).

with a consumption level less than 5MWh/year had to pay an additional 100€ per year. The tax was abolished in January 2018 and replaced by a low fee of about 9€ per year.[19] The abolishment of this contentious tax came after a decision by the constitutional court in June 2017.[20]

3.1.2 Wallonia

In 2013, the Walloon government imposed a dedicated surcharge to finance the GC debt. The amount was insufficient to cover the full cost of the debt but the government decided to cap the surcharge at 13.82€/MWh and did not want an immediate full pass-through of the cost. Part of the cost will be paid later by *future* consumers. To that end, it created a special purpose vehicle (SPV) which bought the GC accumulated by the grid operator to sell them later.

Finally, in 2013 the Walloon government also decided to change the green certificate mechanism *ex-post*, by modifying the granting period from 15 to 10 years. This retrospective change in the rules generated a lot of anger among prosumers who organized themselves in a lobby group and launched a class action against this decision. Despite several attempts by successive governments to find a negotiated solution, the case was brought to Court. The Court validated the government's decision, but the case is still under appeal.

3.2 Financing net metering

Both the governments in Flanders (in 2013) and Wallonia (in 2014) decided to impose a prosumer fee. This prosumer fee is based on the PV capacity (in kWp) and it is designed as a contribution of the prosumers to the grid costs. Brussels instead decided to stop net metering in 2020, also for PVs that were installed before.

The imposition of new fees on prosumers was an extremely contentious issue. It was seen by prosumers as an attempt by the governments to renegotiate their promises and lower the return on their investment ex-post. For this reason, earlier attempts to impose such a fee were successfully challenged in courts by some prosumers. Later, the fees were effectively implemented in 2015 in Flanders and in 2020 in Wallonia.

[19]Source: https://www.tijd.be/politiek-economie/belgie/vlaanderen/hoe-tommelein-de-turteltaks-van-100-naar-9-euro-doet-zakken/9935978.html (consulted on 21/09/2020).

[20]This tax is known as the "Turteltaks", after the name of the Flemish minister in charge of energy, Annemie Turtelboom who imposed it. The opposition against the tax eventually caused her to step down as minister.

3.3 Investment support

The investment rebates and the tax credits were financed by the general budget of the regions and the federal government, respectively. This involved only a limited debate because financing through the general budget is less visible as it is just a small part of the overall government budget.

3.4 Evolution of electricity prices

The cost of the subsidies and the way they were financed translated into changes in electricity prices. Figure 6 shows the evolution of the retail price of electricity for a representative consumer in Flanders, Wallonia and Brussels. Prices started to diverge in 2013, reflecting the different policy choices made by the regions. As can be observed in the figure, the commodity price is almost the same in the three regions and the price differences mainly come from the extra costs to support green energy. The difference between Flanders and Wallonia partially reflects the choice made in Wallonia to transfer a part of the GC debt to future consumers, while Flanders decided to pass most of the debt to current consumers. In Brussels, where there is almost no GC debt, the electricity price is the lowest.

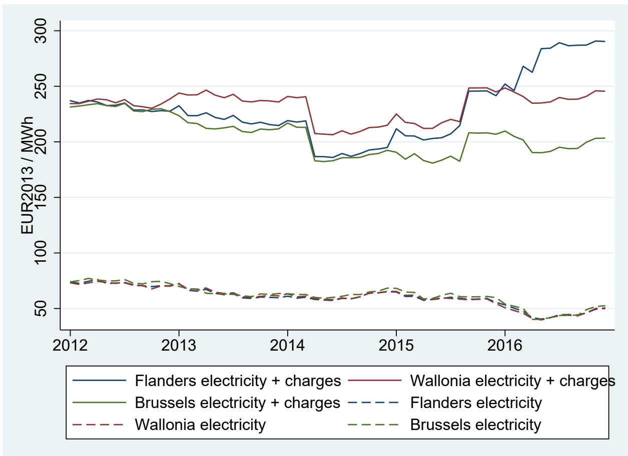

Figure 6: Electricity prices per region, 2012-2016

Notes: This graph shows the evolution of the electricity price in the three regions. The retail price (solid lines) is the sum of the electricity price (dotted lines) and the different taxes and surcharges. Data source: Hindriks and Serse (2021).

3.5 Political responsibility

The support to green energy is a regional competency and each region has a minister in charge of energy. The regional governments are appointed for five years, following the regional elections that took place in 2004, 2009, 2014 and 2019. The electoral system is a proportional system and the political spectrum is highly fragmented. Regional governments are governed by a coalition of parties, usually at least two in Wallonia and three in Flanders, formed after the election.

The generous subsidy programs were implemented by the government during the legislature of 2004-2009.[21] The government acting during the 2009-2014 legislature had to adapt and later suppress the GC mechanism. During this term, it became apparent that, on the one hand, the investors benefited from a high return and, on the other hand, the mechanism was costly and that these costs would be passed through to consumers. Furthermore, earlier unsuccessful attempts to impose a prosumer fee were discussed during this term. The government appointed for the 2014-2019 term had to impose corrective measures to finance the GC debt and the net metering. As we explained above, the government in Flanders had the intention to pass all the costs to consumers and, to that end, it imposed a flat tax on electricity consumption and a prosumer fee in 2015. The government in Wallonia was more prudent and passed only part of the GC debt to consumers. The prosumer fee that the regulator wanted to impose was challenged by the government, and it became a political issue during the campaign for the 2019 election.

These controversies were part of the political debate and largely echoed in the press. The issue is important because it is related to the energy transition and the policies that should be implemented to address climate change. The discussions on the subsidies given to solar PVs illustrate that the energy transition is a costly process and that costs and benefits were unequally shared among citizens i.e. there are important redistributional concerns associated with climate change.

It should finally be noted that the green parties were not necessarily the main advocates for those policies. In Flanders, the green party did not approve the policy in parliament and has not been part of the regional government since 2004. In Wallonia, the green party was part of the majority only for the period 2009-2014. Table 6 in Appendix B details the composition of regional each government.

[21] In Flanders, the program was approved by parliament just before the election of 2004 by an alternative majority. The parties who approved it formed the government after the 2004 election, which was responsible to carry out the decision.

4 Voters' responses to the subsidy programs

The previous sections discussed how the generous subsidies led to the massive adoption of PVs, which in turn implied substantial financial costs and an intense political debate. In this section, we provide evidence on the impact of the policies on voters' responses. We will first discuss the hypotheses, and the empirical model to evaluate them. Next, we discuss our findings.

4.1 Hypotheses

We consider two main hypotheses on the impact of the subsidy programs on voters' responses. Our first hypothesis is the "buying votes" hypothesis developed by Biais and Perotti (2002) and adapted to the case of solar PV by Ovaere and Proost (2015). Accordingly, adopters who benefited from the subsidies (and prospective future adopters) reward the government that designed the subsidy scheme by voting for the responsible parties. Furthermore, adopters have a special interest in the solar policy and may vote for the incumbent to keep their promised high return on PV installations. According to this buying votes hypothesis, we should observe a positive prosumer effect on ballots.

A second hypothesis is that voters punish the government because they are ending up paying their electricity much higher. Consumers who did not benefit from the subsidies punish the government if it becomes apparent that they end up paying a considerable part of the subsidy costs without receiving any financial benefit, and only small environmental benefits compared to its cost. Furthermore, prosumers who did receive subsidies may also punish the government that established the program, because the government changed the program by imposing corrective measures.

4.2 Model and data

To evaluate these hypotheses, we exploit detailed cross-sectional variation in the cumulative PV adoption levels across the country. We specify a model for the election outcomes at the municipality level for all the regional election years (1995, 1999, 2004, 2009, 2014 and 2019). We consider the following regression model:

$$Y_{mt} = \gamma PV_m \times I(t \geq 2009) + \beta X_m \times I(t \geq 2009) + FE_m + FE_{rt} + e_{mt} \quad (1)$$

where Y_{mt} denotes the vote share of the 2004-2009 government parties in municipality m and election year t, PV_m is the cumulative adoption rate in municipality m at the end of the first (most generous) phase of the GC policy, X_m are local demographics, $I(t \geq 2009)$ is an indicator for elections since 2009, and FE_m and FE_{rt} are fixed effects per municipality m and per region r and election time t ($r = \{Flanders, Wallonia, Brussels\}$).[22] Note that we observe data at the municipality level only since 2014. Appendix C explains how we combine this with data at the (more aggregate) "canton" level during the earlier periods.[23]

Our identification strategy is similar to that of a difference-in-differences estimator where we consider the treatment intensity. See for example Acemoglu *et al.* (2021) for a related recent example in a voting context. The parameter γ is our estimate of interest. It captures how votes changed differently in areas with more PVs while controlling for time-invariant differences between municipalities and aggregate trends over time in each region. Additionally, we control for local changes in votes that can be explained by local demographics that are important for adoption behavior (see De Groote *et al.* (2016) in this context). We include the local distribution of housing and geographic characteristics (population density, home ownership, number of rooms, year of construction), as well as individual and household characteristics (income, household size, gender, nationality, education).

If voters are affected by the subsidization policy, we expect $\gamma \neq 0$ for two reasons. First, if votes by PV adopters change, we should see larger effects in these areas. Second, if votes of others change, we can still expect a larger effect in these areas as people living close to PVs are expected to be more aware of this policy issue. As we explained in the introduction, this identification strategy is motivated by literature finding that salience of a policy is important in explaining behavior (Chetty *et al.* (2009), Huet-Vaughn (2019)).

We also discuss the results of richer specifications. First, to provide robustness on the total effect on votes, we allow for year-specific effects γ_t (and β_t) instead of using the indicator $I(t \geq 2009)$. This allows us to discuss dynamic effects and to test for a pre-trend in the data. We then discuss a specification with regional effects γ_r to see if the difference in policies within the

[22] The first phase of the policy ended after 2012 in Flanders and in 2014 in Wallonia. Brussels did not make major adjustments in our sample period so we include all adoptions. We define government parties by region: in Flanders, we use all votes for CVP/CD&V, VU, NV-A, SP.a, SLP/Spirit and (Open) VLD, including cartels formed among them. For Wallonia, we use PS and PSC/CDH. For Brussels we use PS, PSC/CDH, ECOLO, (Open) VLD, SP.a, SLP/Spirit, CVP/CD&V and the cartel votes CD&V-NV-A (we do not include VU/NV-A separately as they never had a minister in the government of Brussels).

[23] We use public information provided by the Belgian government. For the years 1995-1999 the information was obtained from http://www.ibzdgip.fgov.be/. For 2004-2019, we obtain the data from https://verkiezingenXXXX.belgium.be/ with XXXX referring to the election year. We use data from 208 cantons and 589 municipalities, but we drop 15 municipalities in 2019 because mergers gave rise to a new composition.

country also led to different voting patterns.

Next, we extend the main model to better understand the sources of the net impact on votes by separately identifying the impact of neighbors of PV adopters. Since we do not have data at the individual level, we look instead at how households are affected by adoptions in neighboring municipalities, while controlling for the own adoption rate:

$$
\begin{aligned}
Y_{mt} &= \gamma_1 PV_m \times I(t \geq 2009) + \beta_1 X_m \times I(t \geq 2009) \\
&+ \gamma_2 \widetilde{PV_m} \times I(t \geq 2009) + \beta_2 \widetilde{X_m} \times I(t \geq 2009) \ + FE_m + FE_{rt} + e_{mt} \qquad (2)
\end{aligned}
$$

where $\widetilde{PV_m}$ and $\widetilde{X_m}$ are the adoption rate and characteristics of neighboring municipalities of m.[24] The parameter γ_1 still captures the total effect of adopters and their closest (within-municipality) neighbors, while γ_2 now only captures a neighbor effect (between adjacent municipalities).

Finally, we will analyze which parties lost and gained votes. To study this, we repeat the main analysis with different outcome variables Y_{mt}. Instead of the vote share of the incumbent parties the outcome variables become the vote shares of different (groups of) political parties. The composition of these groups can be found in Table 7 in Appendix B.

4.3 Results

Table 3 presents the results from our main model (equation (1)). Summary statistics on votes and adoption can be found in Table 2 and statistics on local demographics are in Table 8 in Appendix D. In Regression 1 we control for local fixed effects, as well different time fixed effects for each of the three regions. We find that a 10 percentage point increase in the local adoption rate decreases the 2004-2009 government vote share by 3.7 percentage points. In Regression 2 we additionally control for a set of local demographics, interacted with a dummy equal to one from 2009 on. This controls for vote changes that can be attributed to voter characteristics rather than adoption. We find that this cannot explain the negative impact. Adopter characteristics are rather related to an increase in votes for the incumbent parties, making the decrease due to adoption raise to 7.9 percentage points.

Regression 3 shows the impact by election year, with the election year before the policy change (2004) as the base. The non-significant effects in 1995 and 1999 confirm that there was

[24] We use a row-normalized contiguity matrix.

	Mean	SD	Min	Max
Vote share 2004-2009 government	0.601	0.171	0.093	0.904
Vote share radical left	0.035	0.043	0.000	0.268
Vote share green	0.100	0.049	0.027	0.318
Vote share left	0.206	0.111	0.024	0.564
Vote share center	0.304	0.166	0.030	0.783
Vote share liberal	0.227	0.102	0.054	0.727
Vote share radical right	0.092	0.077	0.000	0.397
Local PV adoption rate	0.097	0.042	0.002	0.287
Neighbor PV adoption rate	0.099	0.033	0.000	0.191
Flanders	0.508	0.500	0.000	1.000
Wallonia	0.457	0.498	0.000	1.000
Brussels	0.035	0.184	0.000	1.000

Table 2: Summary statistics, vote and PV adoption

Notes: This table provides summary statistics of our main variables, i.e. the vote shares, local and neighbor adoption rates and region dummies. The unit of observation is an election year (1995, 1999, 2004, 2009, 2014, 2019) and canton (or municipality for the last two election years). The total number of observations is 1995, amounting to on average 332.5 canton/municipality per election year. Neighbor PV adoption rate calculated using row-standardized contiguity matrix.

	(1) Base	(2) + demo	(3) Yearly effects	(4) Regional effects
Local PV adoption rate				
$\times I(year \geq 2009)$	-0.373	-0.793		-0.569
	(0.132)	(0.226)		(0.271)
$\times I(year = 1995)$			0.148	
			(0.128)	
$\times I(year = 1999)$			0.132	
			(0.095)	
$\times I(year = 2009)$			-0.667	
			(0.227)	
$\times I(year = 2014)$			-0.605	
			(0.205)	
$\times I(year = 2019)$			-0.813	
			(0.221)	
$\times I(year \geq 2009) \times Flanders$				-0.578
				(0.259)
$\times I(year \geq 2009) \times Brussels$				3.974
				(6.893)
Municipality FE	YES	YES	YES	YES
Year x region FE	YES	YES	YES	YES
Demographics $\times I(year \geq 2009)$	NO	YES	YES	YES
Observations	1,995	1,995	1,995	1,995
R-squared	0.968	0.971	0.971	0.971
P-value no pre-trend			0.373	
P-value same effect after 2004			0.013	

Linear regression on vote share of 2004-2009 government parties.

Robust standard errors in parentheses, clustered within canton.

Canton level data used in 1995-2009. Municipality-level data used in 2014-2019.

Table 3: Regression results, Model 1

no pre-trend in the votes, providing confidence in the identification strategy.[25] Furthermore, the effect is present in every election after 2004 and significantly larger in 2019. This is consistent with the more recent increases in surcharges on the electricity bill for non-adopters (see Figure 6) and the introduction of the prosumer fee for some of the adopters. Finally, Regression 4 shows a more negative effect in Flanders. This stronger punishment effect is consistent with the larger electricity surcharges in that region, as well as with the introduction of the prosumer fee for adopters of PVs. For Brussels, the results are too imprecise to draw conclusions, due to its small number of cantons and municipalities.

In sum, the main finding from Table 3 is that the incumbent parties received *fewer* votes in municipalities where the subsidization policy was more successful. This is inconsistent with the buying votes hypothesis, according to which adopters reward the incumbent parties. Instead, it is consistent with our alternative retrospective voting hypothesis. A first channel of this hypothesis comes through the voters who did not adopt PVs and hence did not directly benefit from the programs. They would punish the incumbent parties because they realize that the financing costs would be high and be paid to a large extent by non-beneficiaries.

Although the increase in the electricity price affects all consumers, the punishment effect is expected to be more important for the non-adopters who live in municipalities where many people adopted. There are two reasons for this. First, voters have many motives to choose one party over another. The visibility of PVs in the neighborhood can make the PV policy more salient in these areas and therefore have a larger impact on the votes. Second, households might be envious that the subsidy is used to transfer wealth to their direct neighbors. In places where there are few PVs, the beneficiaries of this policy are less visible than in the places where there are a lot of PVs. Furthermore, there is more adoption in richer places (De Groote *et al.*, 2016). Therefore, this policy may generate a Matthew effect, which may be more visible in places where there are more PVs. All these reasons may explain why the punishment is stronger in places where adoption is more important.

An alternative channel of the retrospective voting hypothesis is that the prosumers themselves punish the government because they feel deceived after having to (or expecting to) pay a new prosumer fee, which reduces their initial expected returns. To distinguish between the behavior of prosumers and their neighbors, we run the model specified in equation (2) (see Table 4). Regression 5 starts from Regression 2 but adds the adoption rate of neighboring municipal-

[25]We also found no pre-trend in a specification without control variables or a specification where we interact the control variables with each election year.

ities. We then allow for time-varying effects of the demographics of neighboring municipalities in Regression 6. If the negative voting effect would be explained by punishment by prosumers only, we should not see any impact on the local vote share by the adoption rate in the neighboring municipalities. However, we find a negative impact in both specifications, with effect sizes that are close to our main estimates of interest. This shows that the negative effect is mainly driven by neighbors of prosumers, rather than by prosumers. In regression 6 we even see that the negative effect is only significant for adoption in the neighboring municipalities, and no longer for the local adoption rate. This suggests that prosumers may even reward the government and thereby dampen the negative effect on votes caused by their (within-municipality) neighbors, due to the buying votes hypothesis. However, this result should be interpreted with caution as we cannot reject the hypothesis that the effect of the local adoption rate is significantly different from the effect of the adoption rate in neighboring municipalities.

Finally, Table 5 estimates the main model (equation (1)), but replaces the outcome variable with the vote share of different (groups of) political parties. As there are very few cantons and municipalities in Brussels, we only do this for the two other regions.[26] The pattern in the two regions is quite similar with votes going to the radical left and radical right, and coming from the socialist parties. In both regions, these parties had important competencies in environmental policies and are likely more affected by concerns related to the Matthew effect as subsidies for solar panels are a transfer to more wealthy households (De Groote *et al.*, 2016).[27] Note also that the effects of the liberal parties are different in both regions (p-value of 0.066). This is consistent with the fact that liberals were part of the government that introduced the subsidization policy in Flanders, but not in Wallonia.

Note that we cannot exclude that other parties involved in the government over the past years experienced strong negative effects too. We only detect significantly positive effects for parties that were never in government, both on the left and the right of the spectrum. This suggests that voters were not able to well identify who was responsible for the policy. This is very plausible considering the policy changes that happened later by ministers of different parties. It

[26]We also estimated a model that included the effects for Brussels. These estimated effects were all insignificant and imprecise, and there was almost no change in the estimates for the other regions

[27]Policies that conflict with the party's ideology can influence their electoral effect. In the context of fiscal spending in the US, Huet-Vaughn (2019) suggests that their positive effect of road spending might not hold if the responsible party was the republican party instead of the democratic party as they generally favour smaller budgets. Indeed, Lowry et al. (1998) show that voters hold politicians accountable in a partisan way as they punish republicans and reward democrats for increases in the fiscal scale.

	(5) Neighbor effect	(6) + controls
Local PV adoption rate	-0.505	-0.088
$\times I(year \geq 2009)$	(0.299)	(0.382)
Neighbor PV adoption rate	-0.427	-1.066
$\times I(year \geq 2009)$	(0.230)	(0.373)
Municipality FE	YES	YES
Year × region FE	YES	YES
Demographics $\times I(year \geq 2009)$	YES	YES
Neighbor demographics $\times I(year \geq 2009)$	NO	YES
Observations	1,995	1,995
R-squared	0.971	0.972
P-value local effect = neighbor effect = 0	0.000	0.000
P-value local effect = neighbor effect	0.874	0.179

Linear regression on vote share of 2004-2009 government parties.

Neighbor PV adoption rate and controls calculated using row-standardized contiguity matrix.

Robust standard errors in parentheses, clustered within canton.

Canton level data used in 1995-2009. Municipality-level data used in 2014-2019.

Table 4: Regression results, Model 2

	(7)	(8)	(9)	(10)	(11)	(12)
	Rad left	**Green**	**Social**	**Center**	**Liberal**	**Rad right**
Local PV adoption rate						
$\times I(year \geq 2009) \times Flanders$	0.208	-0.141	-0.430	-0.482	-0.174	0.730
	(0.061)	(0.091)	(0.164)	(0.304)	(0.237)	(0.167)
$\times I(year \geq 2009) \times Wallonia$	0.100	0.141	-0.427	-0.129	0.214	0.230
	(0.084)	(0.093)	(0.181)	(0.233)	(0.211)	(0.100)
Municipality FE	YES	YES	YES	YES	YES	YES
Demographics $\times I(year \geq 2009)$	YES	YES	YES	YES	YES	YES
Year × region FE	YES	YES	YES	YES	YES	YES
Observations	1,995	1,995	1,995	1,995	1,995	1,995
R-squared	0.927	0.918	0.951	0.965	0.935	0.943
P-value no regional differences	0.164	0.009	0.985	0.191	0.066	0.004

Linear regression on vote share of families of parties.

Robust standard errors in parentheses, clustered within canton.

Canton level data used in 1995-2009. Municipality-level data used in 2014-2019.

Table 5: Regression results model 1, per political party

is also consistent with the growth of anti-establishment votes as the result of failed policies.

5 Conclusion

In this paper, we investigated the electoral impact of technology-specific subsidies for parties that introduced them. We considered the generous subsidy programs to solar PVs in Belgium, which led to unexpectedly massive success. The resulting financing problems were the subject of an intense political debate in the subsequent years. We exploited variation in the PV adoption rates across municipalities to evaluate the impact of the subsidy policies on election outcomes. Our results are consistent with retrospective voting, where voters punished the incumbent political parties for a costly policy that highly benefited a relatively small group, without creating sufficient (environmental) gains for others.

This has important implications for green energy policy. Political rather than economic reasons have been used to justify the choice of technology-specific policies to combat climate change over other measures such as a market for carbon emission rights or a carbon tax. Our results indicate that the political objectives of these policies did not materialize, because the incumbent parties actually lost votes from the excessive support for solar panel adoption.

These results give an optimistic message about the role of democracy to improve policy-making, at least in the face of new challenges such as taking necessary measures to combat climate change. However, we need to be cautious about the external validity. The cost of the policy was made very salient through surcharges on the electricity bill, intense political debate and high rates of adoption. It is not clear if the punishment would appear in response to policies of a smaller scale. Nevertheless, a punishment effect was already found before the large increase in costs, suggesting that voters can understand the impact of a subsidy on future taxation. Further research could investigate the role of dedicated taxes to finance subsidy programs on political accountability.

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A Computing the NPV: Model and data sources

This appendix discusses the data sources and assumptions needed to obtain an estimate of the net present value of adopting a PV, as well as the commitments and payments by the government.

A.1 Model

We collected detailed information on the timing and the magnitude of the different support schemes in the three regions. Based on that, we compute the various components of the net present value: NPV_{rjt}, with j denoting the capacity of PV (up to 10kW), the region $r = F, W, B$ (Flanders, Wallonia and Brussels) and the month t (time frame: January 2006-December 2016). We correct for inflation and express net present value in prices of 2013 using the HICP.

A.1.1 Computing the net present value components

We assume the upfront investment cost of a solar PV with capacity size j at month t (p_{jt}) is the same across the three regions r, but the present discounted value of benefits (b_{rjt}) differs. The net present value therefore differs as $NPV_{rjt} = b_{rjt} - p_{jt}$.

The financial returns of adopting a solar PV differ between regions and come in the form of rebates, tax cuts, net metering benefits and green certificates:

$$b_{rjt} = b_{rjt}^{rebate} + b_{jt}^{taxcut} + b_{rjt}^{netmeter} + b_{rjt}^{GC}.$$

Most of these benefits apply over future periods, and we calculate their present value using a monthly discount factor of $\delta = (1+r)^{-1/12}$, where r is the annual real interest rate. We will now discuss these various components in turn.

The rebates b_{rjt}^{rebate} are a percentage of the investment cost p_{jt}. They are usually paid shortly after the investment so we abstract from discounting here. The tax cuts were applicable for a period of up to four years, and are given by:

$$b_{jt}^{taxcut} = \sum_{\tau=1}^{4} \delta^{12\tau} \tilde{b}_{jt}^{taxcut,\tau},$$

where $\tilde{b}_{jt}^{taxcut,\tau}$ is the tax cut applicable τ years after adoption at time t.

The remaining benefit components all relate to future electricity production. We assume that the PVs start generating electricity the month after the investment and they have a lifetime of 20 years ($R^E = 240$). The monthly production (in kWh) per unit of capacity (in kW) is given by a constant capacity factor β and there is a monthly deterioration rate denoted by λ. The net metering benefits are then given by:

$$b_{rjt}^{netmeter} = \delta \frac{1-(\delta^E)^{R^E}}{1-\delta^E} \tilde{b}_{rjt}^{Electricity} - \delta \frac{1-(\delta)^{R_t^{ProsFee}}}{1-\delta} \tilde{b}_{rjt}^{ProsFee}.$$

The first term captures the net metering benefits over the PV's lifetime (R^E), and the second term captures the costs of the prosumer fee over the period ($R_t^{ProsFee}$) that it applies. The variable $\tilde{b}_{rjt}^{Electricity}$ is the monthly benefit from net metering based on the observed electricity price at time t. $\tilde{b}_{rjt}^{ProsFee}$ is the monthly cost of the prosumer fee. If at the installation date, such a fee was not yet in place, we assume people did not anticipate it, i.e. $\tilde{b}_{rjt}^{ProsFee} = 0$. Finally, the adjusted monthly discount factor δ^E is given by $\delta^E = (1-\lambda)(1+\kappa)\delta$, where κ denotes the expected percentage increase in electricity prices to capture changes in future net metering benefits.

Finally, the GC benefits, which are also related to electricity production, are given by:

$$b_{rjt}^{GC} = \delta \frac{1-(\delta_{rt}^G)^{R_t^G}}{1-\delta_{rt}^G} \tilde{b}_{rjt}^{GC}$$

where $\tilde{b}_{rjt}^{GC}$ denotes the monthly benefits from GCs for adoption at time t, and R_t^G number of periods that the GCs are guaranteed. The monthly benefits $\tilde{b}_{rjt}^{GC}$ stem from the GC price. In Flanders, we simply use the fixed price of the GCs applicable at the time of adoption t. In Wallonia and Brussels, the GC price is market based, so we have to make an estimate of the price: we take it to be equal to the expected price at the moment of adoption for the entire period R_t^G. The adjusted monthly discount factor δ_{rt}^G is given by $\delta_{rt}^G = (1-\lambda)(1-\pi)\delta$ where π is the monthly inflation rate, to capture the fact that the model is in real prices while GC benefits were guaranteed at nominal prices. We use a different formulation for Wallonia after the March 2014 reform $\delta_{Wt} = (1-\pi)\delta$ as benefits were then based on PV capacity and not on actual production.

A.1.2 Hypothesis

The assumptions we use are:

- 1 kW produces 850 kWh/year (capacity factor β of 0.0973)
- Yearly deterioration: 1% ($\lambda = 1.01^{1/12} - 1$)
- Lifetime PV: 20 years ($R^E = 240$)
- Inverter replacement not anticipated
- Yearly inflation: 2% ($\pi = 1.02^{1/12} - 1$)

- Annual interest rate: $r = 3\%$

- Grid fee never anticipated

- Yearly expected increase electricity prices: 3.4% (corresponding to estimated monthly trend of $\kappa = 0.0028148$ corresponding to the historical trend)

- Current price of GCs guaranteed at nominal values through investment period

A.2 Data sources

A.2.1 Investment cost

Our starting point is the price index for five capacity sizes (2, 4, 6, 8 and 10 kW) in Flanders from 2006-2013 in De Groote and Verboven (2019). Note however that the authors are cautious about price information before 2009 as it is based on prediction from a German price index (they do not use it in estimations).

We use the most common VAT rate (6%) and extrapolate the data by using four data points that were used by government agency VEA to calculate subsidies in June 2013, December 2013, June 2014 and January 2015 for a 5kW system. We additionally use a data point in February 2018 for a larger system because subsidies were no longer calculated for smaller ones.[28] Finally, we requested the price of a 5kW system on the website of energy supplier, Luminus, to assign a price for the end of 2019.[29] We use this data to calculate the growth rate in the relevant size category since the last observation in De Groote and Verboven (2019) and apply this rate on all capacity options. Finally, we apply cubic spline interpolation to fill in the missing months.

A.2.2 Government policies

Our starting point is again De Groote and Verboven (2019) who describe all federal and Flemish policies until the beginning of 2013. No new policies have been implemented since at the federal level.

For Flanders, additional information was collected on the government website www.energiesparen.be. It contains the reports of the VEA about the newly applicable

[28] Source: https://www.energiesparen.be/overzicht-bandingfactor-zonnepanelen, consulted on 28/02/2020.

[29] Source: https://www.luminus.be/nl/apps/flows/prijs-zonnepanelen/, consulted on 17/01/2020.

granting rates of GCs (we used the same reports to obtain information on investment costs), as well as information on the grid fees.

For the policies that are specific to Wallonia, we use the specific report on green certificates published yearly by the regional regulator and the specific information published on its website. Boccard and Gautier (2015, 2019) contain detailed information on the functioning of the GC market in Wallonia.

Finally, our main source for the policies in Brussel is the regional regulator. Data and information were collected on its website and it provides additional information and data on request.

A.2.3 Electricity prices

As in De Groote and Verboven (2019) we use the electricity price in Belgium, reported every six months by Eurostat and we apply cubic spline interpolation to obtain monthly data. However, from 2012 on we use a region-specific measure with monthly variation, computed by Hindriks and Serse (2021) based on data obtained from the CREG.[30]

B Additional information on regional governments and political parties

Legislature	Flanders	Wallonia	Brussels
2004-2009	**CD&V**, SP.a, VLD, NVA	PS, **CDH**	PS, **Ecolo**, CDH, Open VLD, CD&V, SP.a
2009-2014	CD&V, **SP.a**, NVA	PS, CDH, **Ecolo**	PS, **Ecolo**, CDH, Open VLD, CD&V, Groen
2014-2019	NVA, CD&V, **Open VLD**	**PS**, CDH (2014-2017), **MR**, CDH (2017-2019)	PS, Défi, **CDH**, Open VLD, CD&V, SP.a

Table 6: Composition of regional governments

Notes: The party who had energy minister in bold

[30]At the time of switching between prices indexes (January 2012), the difference between the national and Flemish price was only 0.4%, the difference between the national and the one in Wallonia was 0.7% and the difference with the one in Brussels was 2%.

	Rad left	Green	Socialist	Center	Liberal	Rad right
Flanders	PVDA	Groen	SP.a, SLP	CD&V, NVA	Open VLD	Vlaams Belang, LDD
Wallonia	PTB	Ecolo	PS	CDH	MR, Défi	PP, FN

Table 7: Positionnement of political parties

Notes: All parties were present in Brussels. When a political party changed its name, we use the most recent.

C Further details on the voting model

We use the specification detailed in the main text of the paper for the election years 2014 and 2019, but we lack data at the municipality level for the elections of 1995, 1999, 2004 and 2009. For these years, data are only available at the canton level. A canton is either a municipality or a group of adjacent municipalities. There are 209 cantons in Belgium and 589 municipalities. To include this in a single regression, we proceed as follows.

Let the regression at the municipality level be given by:

$$Y_{mt} = \gamma PV_m \times I(t \geq 2009) + \beta X_m \times I(t \geq 2009) + FE_m + FE_{rt} + e_{mt} \quad (1)$$

In some years we do not observe Y_{mt} but we do observe the canton-level vote shares, defined as $Y_{at} = \sum_{m \in A} w_m Y_{mt}$ with a an indicator for the aggregated unit (i.e. the canton), A the set of municipalities in a and w_m the share of voters that come from each municipality. We assume this share is stable over time and proxied by the share of households living in each municipality, a variable we observe in our data.[31] We can then rewrite the municipality-level regression at the canton level:

$$\begin{aligned} Y_{at} &= \gamma \sum_{m \in A} w_m PV_m \times I(t \geq 2009) + \beta \sum_{m \in A} w_m X_m \times I(t \geq 2009) \\ &+ \sum_{m \in A} w_m FE_m + FE_{rt} + \sum_{m \in A} w_m e_{mt} \end{aligned} \quad (3)$$

The linearity of the regression equation makes it straightforward to apply this. Before estimation we need to calculate weighted averages of control variables, adoption rates, and the dummy indicators that estimate the municipality fixed effects. We can then regress the canton-level vote share on these weighted averages when municipality-level data are not available.

D Additional summary statistics

[31] It is compulsory to vote in Belgium so we expect this to be a good proxy.

	Mean	SD	Min	Max
Ln(population density)	5.752	1.168	3.215	10.100
Income group 2	0.212	0.377	0.000	1.000
Income group 3	0.203	0.364	0.000	1.000
Income group 4	0.178	0.346	0.000	1.000
Income group 5	0.181	0.361	0.000	1.000
% home owned	0.721	0.097	0.252	0.911
% higher education	0.303	0.071	0.127	0.592
% male	0.493	0.009	0.454	0.553
% foreign	0.071	0.075	0.009	0.497
Average household size	2.394	0.145	1.658	2.802
Number of rooms	5.842	0.396	4.202	7.184
Average year of construction house (/1000)	1.962	0.011	1.931	1.982
Neighbors: Ln(population density)	5.686	1.045	0.000	9.233
Neighbors: Income group 2	0.209	0.206	0.000	1.000
Neighbors: Income group 3	0.201	0.185	0.000	1.000
Neighbors: Income group 4	0.193	0.199	0.000	1.000
Neighbors: Income group 5	0.182	0.224	0.000	1.000
Neighbors: % home owned	0.722	0.081	0.000	0.856
Neighbors: % higher education	0.305	0.055	0.000	0.515
Neighbors: % male	0.492	0.024	0.000	0.509
Neighbors: % foreign	0.067	0.059	0.000	0.497
Neighbors: Average household size	2.391	0.149	0.000	2.698
Neighbors: Number of rooms	5.838	0.402	0.000	6.456
Neighbors: Average year of construction house (/1000)	1.956	0.095	0.000	1.981

Table 8: Summary statistics: local demographics

Notes: This table provides summary statistics of local demographics. The unit of observation is the municipality.