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Are renewable energy subsidies effective? Evidence from Europe*

Abstract: We construct an exact measure of the monetary incentive granted to renewable energy source electricity (RES-E) in five large European countries in the period 2000-2010. We find that these policies have been effective in promoting renewable energy, both in the short and in the long run. Indeed, we observe a positive relationship with the production of incentivized energy, as well as a positive impact on installed capacity, effect and in the long run. We also find that feed-in tariffs outperform green certificates in terms of spurring renewable energy production.

Keywords: green certificates; feed-in tariff; renewable energy sources electricity (RES-E); subsidies

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1. Introduction

One of key pillars of the European Union energy strategy of the past ten years has been the focus on promoting renewable energy sources. At the beginning of the 21st century, the EU Directive 2001/77/EC first (EU, 2001) imposed mandatory targets for renewable energy. This process has culminated in 2009 with the EU Directive 2009/28/EC (EU, 2009), that sets the target of a 20% share of energy from renewable sources in the Community's gross final consumption of energy. In accordance, member state countries have implemented a number of different policies in order to increase the production of electricity from renewable sources. Such support schemes are now being progressively phased out, due to rising policy costs and to the significant reduction in renewable investments costs which has occurred also thanks to these policies. This change of course is also visible in the EU policy discussion, as testified by reduced focus on renewables in the recently proposed 2030 energy and climate strategy. It is thus an appropriate time for evaluating the effectiveness and efficiency of these policies.

In this paper, we investigate how monetary incentives to renewable energy affect the production of renewable energy sources electricity (RES-E). We consider five large European countries: France, Germany, Italy, United Kingdom and Spain, over the period 2000-2010 and we collect information on the exact amount of incentive granted, distinguishing by energy source and instrument adopted (i.e. feed-in tariff or green certificates). This represents an improvement with respect to the literature, which generally adopts simpler measures to quantify these policies.

We consider three different indicators of RES-E production: incentivized production, total production and installed capacity and we regress them on our quantitative measures of incentives. More precisely, we use the amount of incentives granted as well as the corresponding average tariff. Our results suggest that these policies have been effective in promoting renewable energy, both in the short run, as we observe a positive relationship with the production of incentivized energy, and in the long run, as there is a positive relationship with the installed capacity. In terms of policy instrument, we find that Feed-in Tariffs (FiT) perform better than Green Certificates (GC): the former policy is more efficient in promoting RES-E production.

The paper is structured as follows: Section 2 discusses the literature on the effectiveness of renewable energy policies, Section 3 presents the policies that have been implemented in the five countries considered in the econometric analysis, while Section 4 describes the data collected. Section 5 presents the methodology adopted, Section 6 shows the results, while Section 7 discusses and concludes.

2. Literature review

Several authors have focussed on the drivers that push renewable energy development. Most of these papers test the effectiveness and the efficiency of policies that promote the renewable electricity. The literature investigates the topic from a qualitative as well as quantitative point of view.

In the first line of research we find the analysis by Mitchell et al. (2006). The authors compare the German feed-in tariff with the renewable obligation mechanism enhanced in England and Wales, which works as a green certificates market. The former is esteemed to be more effective in promoting the deployment of renewable energy, as it reduces risk for generators in a more effective way. Bird et al. (2005) focus on wind power development in the US and suggest that state tax and financial incentives, as well as State renewable portfolio standards (which are a kind of green certificate mechanism), have an important effect on energy development. Alagappan et al. (2011) consider 14 markets in North America and Europe and find that renewable energy development has been more successful, in terms of installed capacity, in countries that adopt feed-in tariffs. Haas et al. (2011) review RES-E promotion strategies in the EU through the discussion of several case studies and conclude that technology specific financial support measures generally were more efficient and effective. Regarding the comparison between different support schemes, they suggest that feed-in tariff systems are effective at relatively low additional cost for customers. They are preferable to green certificates for the ease of implementation and the lower administrative costs. Fagiani et al. (2013) simulate the evolution of a hypothetical power sector similar to the Spanish system adopting a system-dynamic approach and conclude that a tariff mechanism could get better results than a certificates mechanism, although the performance depends on the regulators' choices. However, if investors' risk aversion is moderate, the certificates mechanism allows to obtain the desired level of renewable energy with good cost-efficiency.

One of the first econometric analyses is presented by Menz and Vachon (2006), which investigate the impact of wind power incentives in 39 US states adopting a cross-sectional approach. The wind installed capacity is regressed of four policy dummy variables, which are significant: there is a positive relationship between renewable portfolio standards (RPS) and wind power development. More recent analyses benefit from a longer time series and estimate panel models. Carley (2009) finds that renewable portfolio standards do not appear to be a significant predictor of the share of renewable energy generation out of the total mix in 50 US states over the period 1998-2006, while being positively related, as expected, with total renewable electricity generation. Delmas and Montes-Sancho (2011) find that RPS have a negative impact on investments in renewable capacity. On the other hand, mandatory green power options have a significant impact on installed renewable capacity. Groba et al. (2011) consider the solar photovoltaic (PV) and onshore wind in 26 EU countries, finding that feed-in tariffs have driven an increase in capacity development.

The measure for these policies has improved over time. The first papers use a simple dummy variable, one for each renewable electricity promotional instrument (Menz and Vachon, 2006; Carley, 2009; Yin and Powers, 2010; Shrimali and Kniefel, 2011). Additionally, some authors consider a state-wise cumulative sum of these dummies, thus constructing a measure of the number of years that the RES-E promotion policy has been effective (Menz and Vachon, 2006; Yin and Powers, 2010). A more sophisticated measure of the impact of the subsidies has been proposed by Yin and Powers (2010): the incremental percentage requirement, which is the mandated increase in renewable generation, expressed as a share of all generation. For a given state *i* and period *t*, it is defined as the nominal requirement times the coverage, i.e. the proportion of sales of the utility industry covered by RPS, times total retail sales, minus the existing, i.e. the renewable generation in year *t* that, if generated in later years would be eligible to fulfil the RPS requirement in state *i*. All this quantity is considered in relative terms with respect to total retail sales for the same state *i* and period *t*. Alternatively, Groba et al. (2011) quantify the Return On Investment (ROI), i.e. how much a potential investor can learn if she invests in a renewable energy plant, for a given dimension, tariff and expectation life of the plant. The index relates the total profit and the lifetime costs of the plant. When the policy is not adopted the tariff is set equal to 0, so the index captures the absence of subsidies. These measures for the presence of instruments to stimulate the renewable energy usage generally display a positive and statistically significant coefficient.

As for the control variables in the econometric analyses, they can be classified in four groups.

The *energy variables* usually account for energy needs, i.e. energy consumption, which captures the level of development on an economy (Carley, 2009; Marques et al., 2010, Groba et al., 2011, Marques et al., 2011, Shrimali and Kniefel, 2011) and energy imports, either in absolute value (Groba et al. 2011, Marques et al. 2010, 2011) or net imports (Yin and Power, 2009). These variables usually positively affect RES-E production. The dependence on imports is assumed to increase renewable-based electricity not just for economic issues but also for security of supply issues. Delmas and Montes-Sancho (2011) control for the total number of customers served by the utility and the share of residential customers who purchase RES-E or pay for renewable energy development. The electricity price (Carley, 2009; Yin and Power, 2009; Shrimali and Kniefel, 2011; Delmas and Montes Sancho, 2011) or the fossil source prices (Marques et al. 2010 and 2011; Shrimali and Kniefel, 2011) are often introduced as controls to check if their variation influence the renewable energy production. CO_2 emissions (Marques et al., 2010 and 2011; Delmas and Montes Sancho, 2011), the percentage of GDP attributable to petroleum and coal products (Carley, 2009) and the contribution of fossil fuels to electricity generation (Marques et al., 2010; Groba et al. 2011; Delmas Montes-Sancho, 2011; Marques et al., 2011; Shrimali Kniefel, 2011) are included to check if pollution and dependence on fossil fuels can stimulate RES-E electricity generation. Finally, some authors control for the level of competition in the electricity sector, including some measure of market deregulation (Carley, 2009; Delmas Montes-Sancho, 2011) or whether the utility is state owned (Delmas Montes-Sancho, 2011), where the underlying hypothesis, supported by the econometric analysis, is that publicly owned utilities would be less responsive to renewable policies than investor owned electric utilities.

The *economic variables* usually include GDP or GDP per capita, measured at country or state level (Carley, 2009; Marques et al., 2010; Yin Powers, 2010; Delmas Montes-Sancho, 2011; Groba et al., 2011; Marques et al., 2011; Shrimali Kniefel, 2011). It is generally positive and significant. Some authors also include the unemployment rate (Delmas Montes-Sancho, 2011) and control for other subsidies and tax incentive policies (Carley, 2009).

The *political variables* usually considered in the literature are a dummy for the EU membership in 2001, as in that year the Directive 2001/77/EC first set mandatory targets for member countries, some controls for the political orientation of the Government or the Parliament (Carley, 2009; Yin Powers, 2010; Delmas Montes-Sancho, 2011; Shrimali Kniefel, 2011) and the number of per capita state and local empolyees in natural resources governmental positions (Carley, 2009), which represents the capacity of bureaucracies to respond to environmental issues.

Finally, some *geographical variables* account for country characteristics, such as land area, which proxies for RES-E installations potential (Marques et al., 2010; Groba et al., 2011; Marques et al., 2011), some measures of solar, wind, biomass potential (Menz Vachon, 2006; Carley, 2009; Delmas Montes-Sancho, 2011) and population growth (Carley, 2009).

A brief summary of the variables used in the literature is reported in Table 1.

[INSERT TABLE 1 ABOUT HERE]

The data availability has improved over time, and more recent analyses consider more than one source: most authors analyse renewable energy, considering all sources or excluding hydropower, as this source has developed without subsidies. Previous works generally consider two alternative dependent variables: RES-E capacity and RES-E generation. The installed capacity as well as the energy production are considered both in absolute or relative terms. Only Shrimali and Kniefel (2011) suggest a different dependent variable that encompasses both aspects: the ratio between the installed capacity and renewable-based electricity generation. Although the denominator is fixed, the numerator differs, creating five different dependent variables: total green capacity, total no hydro renewable capacity, geothermal capacity, biomass capacity, solar capacity and wind capacity. A synthesis of the dependent variables used in literature is provided in Table 2.

[INSERT TABLE 2 ABOUT HERE]

These papers investigate the main drivers of renewable energy production, with a particular focus on the impact of incentives. However, to the best of our knowledge, no study quantifies the exact amount of subsidies. We contribute to the literature by collecting punctual data on the amount of subsidies granted in five EU countries in the period 2000-2010 and analysing the effect of tariffs on both incentivized energy and installed capacity.

3. The policies implemented

The main policies used by European governments are the Feed-in Tariff (FiT), the Feed-in Premium and the Green Certificate (GC). FiT usually include three key provisions: (1) guaranteed access to the grid; (2) stable, long-term purchase agreements (typically, about 15-20 years); and (3) payment levels based on the costs of RE generation (Mendonça 2007). The FiT is also known as fixed-price policy as it includes a premium payment and a constant over the spot market electricity price. It gives a fixed amount of money paid for renewable electricity production and an additional premium on top of the electricity market price.

The Feed-in Premium instead offers a premium on top of the spot market electricity price (Couture et al., 2010). This implies that the total price received per kWh by the producer is less predictable in the premium scheme than under a FiT, as it depends on the electricity price.

The third instrument is the Green Certificate. With this instrument the government defines the targets for renewable-based electricity and obliges the generators at their fulfilment. A market for renewable certificates is established and their price is set following demand and supply conditions. In recent years a weight certificate among technologies has been introduced. The generators are obliged to supply or purchase a certain percentage of electricity from renewable sources and have to submit the required number of certificates to demonstrate the compliance. The agents obliged may obtain certificates in three ways:

- from their own electricity generation;
- by purchasing renewable electricity and associated certificates;
- by purchasing certificates without purchasing the actual power from a generator.

The FiT policy guarantees a stable and secure market for investors, raising a hedge against the volatility of electricity price and enhances market access for investors and participants. On the other hand, it has a number of limitations. It distorts electricity market prices and does not directly address the high up front costs of renewable energy technologies. Finally, it does not encourage direct price competition between project developers.

The GC system guarantees a strong regulation of capacity development and costs less than the FiT to public finances. However, as it does not distinguish the incentive across technologies, it promotes more mature technologies and is not able to favour less mature, and more expensive, technologies. Additionally, it is less attractive to investors because of market fluctuations: in case of overinvestment the price of the certificate could theoretically drop to zero.

As shown in Table 3, the FiT policy is widely adopted in the five considered countries. Indeed, four of this countries – France, Germany, Italy and Spain – have adopted it from the beginning and United Kingdom, while relying initially on Green Certificates to promote renewable energy, recently moved to a FiT.

[INSERT TABLE 3 ABOUT HERE]

The first two countries to introduce a policy in support of renewable energies have been Germany and United Kingdom in 1991 with two different instruments: Strom EinspG, a FiT, and Renewable Non-Fossil Fuel Obligation, a Green Certificate mechanism. These measures have been replaced by the EEG in 2000 and by the Renewable Obligation in 2002, respectively. One year later the Italian government introduced the FiT CIP 6 and Spanish energy sector deregulation law (1997) introduced the Regimen Especial, both still in force, while France introduced the Obligation d’Achat in 2000.

The French Contrat d’Achat is a FiT. It has been introduced in 2000 and works as a tipical FiT: the fixed tariff is composed by two parts: the electricity price and the premium. The electricity generated under the Contrat d’Achat has purchases obligation and the contract expires after 15 years.

The Erneuerbare-Energien-Gesetz, the German FiT, is a fixed tariff that includes both support payment and the electricity price. The scheme is in force since 2000 and has been introduced by the Renewable Energy Sources Act. The tariffs differ among technology and project size and decrease over the years.

The Italian system is more complex. The CIP 6, a FiT, was introduced at first in 1992, but since 2002 a Green Certificate mechanism is implemented. However, due to initial excess demand, the authority intervened by buying the unsold certificates. Since 2006 there is also a Feed-in Premium for solar photovoltaic plants only.

Spain adopts a Feed-in Tariff and a Feed-in Premium and the generator can choose the instrument. As the other cases, the tariffs differ among technology and plants size, are adjusted to inflation, cost of technology used and market development of the technology. The two instrument are available since 1997 and are included in the Royal Decree 2017/1997 and in the Law on the Electricity Sector.[1]

Great Britain chose a Green Certificate, the Renewable Obligation. In 2010 a FiT was implemented. It can be broken into two components: the generation payment, a fixed payment for every kWh generated by the plant and the export payment, a fixed payment for every kWh exported to the grid. Figure 1 depicts the introduction of different policies in the five countries over time. Due to escalating costs, and public budget constraints, most of these incentive schemes are now being phased out.

[INSERT FIGURE 1 ABOUT HERE]

4. The data

We collect data from the annual reports provided by the national energy authorities. The data for French incentives are available on annual reports realised by the Comision de regulation de l'Energie (CRE). The German government describes the instrument EEG with annual reports; in Italy the Gestore dei Servizi Energetici publishes some report on renewable energy support policies. The Spanish authority Comision National del Energia (CNE) produces information on energy policies and the British OFGEM publishes an annual report. We collect three variables from these sources: incentivized energy, amount of incentives and tariffs. Data are for five countries (France, Germany, Italy, Spain and United Kingdom), over ten years (2000 – 2010) and five sources (bioenergy, geothermal, hydropower, solar PV and wind power), distinguishing by the type of policy (FiT and GC).

The incentivized RES-E production is a measure the quantity of renewable-based electricity generation produced thanks to government subsidies. The amount of incentives represents the total expenditure for each government. The tariff is the official tariff the governments use to stimulate green electricity. When premium tariffs are available we take the average tariff in order to capture the real value of kilowatt for hour. When the official value is not available, we estimate it relating

[1] http://www.res-legal.eu/search-by-country/spain/tools-list/c/spain/s/res-e/t/promotion/sum/196/lpid/195/

the amount of incentives and the incentivized energy. The total amount of incentives granted over time is reported in Figure 2:

[INSERT FIGURE 2 ABOUT HERE]

Germany has been the most generous country, followed by Spain and Italy. All countries display an increasing trend over time. Figure 3 reports the average tariff for each country across different sources. As the different technologies might receive substantially different financial support, such average is simply suggestive of the different trends across countries.

[INSERT FIGURE 3 ABOUT HERE]

4.1 The Dependent variables

We adopt three different dependent variables to assess the impact of the policies: incentivized RES-E production, total RES-E production and total RES-E installed capacity.

Incentivized RES-E production (incprod). Although it is rather obvious to expect a strong positive relationship between incentivized energy and subsidies, it is less obvious whether and how the control variables affect the incentivized energy. Additionally, we test whether different sources and policies might affect differentially the incentivized energy production. We collect information on incentivized energy from specific national energy authority reports.[2]

Total RES-E production (totprod). Not all renewable-based electricity benefits from subsidies. Thus, we investigate if the impact of subsidies on total renewable energy production is significant. Within this framework it is interesting to investigate if and how control variables, as well as source and policy dummies are significant. We collect data from Energy Information Administration (EIA) International Energy Statistics database.

Total RES-E installed capacity (totcap). When looking at the impact of subsidies, we are interested in their longer term impact on renewable energy generation, thus one has to look at the installed capacity, which reflects the investments undertaken. Data are collected from the International Energy Agency database.[3]

We expect a strong positive correlation between policies and incentivized energy, while the relationship between policies and total renewable energy production is non-obvious. Finally, if the

[2] France: Commission de Régulation de l'Énergie, CRE; Germany: Erneuerbare-Energien-Gesetz, EEG; Italy: Gestore dei Servizi Energetici, GSE; Spain Comisiòn Nacional de Energìa, CNE; United Kingdom: Office of the Gas and Electricity Markets, OFGEM.

[3] Solar PV missing data came from European Photovoltaic Industry Association, EPIA, wind power missing data came from European Wind Energy Association， EWEA.

policies are effective we should find a positive and significant relationship between incentives and total installed capacity.

4.2 The Explanatory variables

As explanatory variables in the model we include two alternative renewable policy measures, plus a number of controls. The measures for renewable policy proposed are two.

Amount of incentives (incent). As discussed above, we collect the real value of the grants in the last ten years, for five countries and distinguishing by source and policy. The total national expenditure promoting renewable energy should have a positive impact on incentivized energy but should have also a positive indirect effect on total renewable energy generation and installed capacity. In the last two cases it is important to understand the role of hydropower. Indeed, this renewable source developed first in most countries and for this reason a lot of its installed capacity and production is not incentivized. The information on the amount granted is extracted from the reports released by the national energy authorities.[4]

Tariff. The tariff that promotes renewable energy is usually different across countries, sources and policies. The effect on the three dependent variables is more indirect that in the case of incentives but we expect however a positive influence. The relationship should be stronger with incentivized energy and weaker with renewable generation and installed capacity. The reports published by national energy authorities provide the average tariff paid to promote renewable-based electricity.[5]

Among the controls, we include the following variables.

Income per capita (gdppc). This variable is country specific and is measured in constant $ PPP (reference year is 2005). According to the literature, we expect that higher levels of per capita income lead to a more intensive use of green energy in terms of incentives, total renewable output and installed capacity, via a higher willingness to pay for green investments and to vote for green policies. The data are collected from World Databank provided by World Bank.

CO2 emissions (co2pc). This quantifies the emission of carbon dioxide per capita due to the electricity consumption. High levels of emissions should have a positive effect on RES-E production and installed capacity. However, this variable has often a negative sign in the literature. The data come from the EIA dataset.

Share of electricity production from fossil sources (fos). This variable quantifies the share of electricity produced by oil and natural gas, the main fossil resources. We include this variable, following the literature, to test the relative importance of these sources in the electricity market. This data is collected from EIA International dataset.

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[4] See footnote 2.
[5] See footnote 2.

Net electricity exports (netelexp). The net exports of electricity is a proxy for energy security: countries with high levels of imports are expected to have a stronger interest in stimulating renewable energy, in order to achieve energy independence. The data is collected from EIA International dataset.

Electricity prices (elprice). We include the price of electricity in €/kwh. The effect of electricity price has different interpretations in the literature. Marques et al. (2010) suggest that an increase in electricity price should stimulate renewable energy, while Yin and Power (2010) expect two possible effects: one positive due to the rise of electricity price; one negative due to the possibility of extra costs shifting to renewable energy. Data is sourced from Eurostat.

Following the literature, we also include some political controls.

Cabinet composition (govparty). The cabinet composition describes the political orientation of the government party following the Schmidt index. The variable ranges from 1, which corresponds to "hegemony of right-wing parties" and 5, "hegemony of social-democratic and other left party". The left party is expected to be more sensitive to environmental issues. Previous literature focused on US market, however in European countries the renewable energy policies are managed by the European Union through directives that the governments have to implement. As a consequence, in the European contest this variable might not be significant. The data is provided by Armingeon et al. (2008).

Finally, we include country and year dummies, which allow us to identify country specific effects as well as to capture any time shock that might affect identically the countries in the sample. Additionally, we include dummies for the different energy sources as well as for the instruments (green certificate versus feed-in tariff). This latter dummy allows to understand which mechanism is more effective in promoting RES-E.

A brief explanation of the variables is reported in Table 4.

[INSERT TABLE 4 ABOUT HERE]

5. Methodology

Apart from a first attempt by Menz and Vachon (2006) to investigate the effectiveness of RES-E subsidies in a cross-sectional perspective, more recent analyses dwell on panel data analysis. The approach has been to estimate alternative models, such as pooled OLS, fixed effects (FE) or random effects (RE) models (Yin and Powers, 2009; Shrimali and Kniefel, 2011). Another popular estimator is the fixed effects with vector decomposition (FEVD), which is equivalent to the FE estimator, with the exception of the time-invariant and rarely changing variables, which are decomposed in an explained and unexplained component (Carley, 2009; Groba et al., 2011; Marques et al. 2010). Delmas and Montes Sancho (2011) adopt a two stage estimator, implementing a logit model in order to predict the adoption of renewable energy subsidies and using the predicted variable in a Tobit model to understand if it can explain the renewable energy capacity. Finally, Marques et al. (2011) choose a quantile regression to describe the entire conditional distribution of the dependent variable.

Following the literature, we take advantage of the panel structure of our data. We first analyse the data adopting a pooled OLS estimator. Then, we estimate both fixed and random effects models. Finally, we report the results obtained with the Hausman Taylor estimator (Hausman Taylor 1981, Amemiya MaCurdy 1986), which fits a random effects model allowing for some covariates to be correlated with the unobserved individual effects. The estimating equation is:

$$ren_{ctsi}=\beta_1 support_{ctsi}+ \beta_2 gdppc_{ct}+ \beta_3 co2pc_{ct}+ \beta_4 fos_{ct}+ \beta_5 netelexp_{ct}+ \beta_6 elprice_{ct}+ \beta_7 govparty_{ct}+ \beta_8 greencert_{cti} +\gamma CD_c+\delta SD_s +\theta TD_t+\varepsilon_{ctsi}$$

where *ren* is one of the three measures of RES-E production we construct, namely *incentivized RES-E production (incprod)*, *total RES-E production (totprod)* and *total RES-E installed capacity (totcap)*, and *support* is one of the two different measures of support constructed: the *amount of incentives (incent)* or the *tariff*. *greencert* is a dummy that assumes value 1 if the sum is granted through a green certificate mechanism and zero for feed-in tariffs, *CD* is a set of country dummies, *SD* is a set of source dummies and *TD* are the time dummies.

6. Results

We first present the results considering as dependent variable the *incentivized RES-E production*. Table 5 reports the results where we consider the *amount of incentives* as explanatory variable. As expected, across all different specifications we find that the coefficient attached to the amount of incentive is positive and significant: the more subsidies are granted, the larger the production of incentivized energy. GDP per capita has a positive coefficient, suggesting that richer countries produce more incentivized energy. We find that the other controls are generally poorly significant. The share of electricity from fossil sources displays a positive coefficient, which is however significant in the FE model only. The electricity production from fossil fuels displays a negative and significant coefficient, suggesting a substitution effect: the higher the price, the lower the production of renewable electricity. This result is however counterintuitive. As concerns the country effects, we observe that Italy and Spain are associated with positive and significant coefficients, thus suggesting that these countries produce more incentivized RES-E that the reference country, i.e. France. As concerns the different sources, the reference class is bio-energy: only geothermal displays a negative and significant coefficient, suggesting that incentivized production from this source is statistically lower than in bio-energy. Interestingly, we observe a negative and significant coefficient for the green certificate dummy, which suggest that, controlling for the amount of subsidies, the green certificate is associated with lower incentivized RES-E production, relative to the feed-in tariff.

[INSERT TABLE 5 ABOUT HERE]

If we consider our second measure of incentive, the tariff, we observe that it displays a positive and significant coefficient, as reported in Table 6. Higher tariffs at time *t-1* are associated with larger incentivized RES-E production at time *t*. As concerns the other control variables, we get results similar to those reported in Table 5, as expected. GDP per capita is positive and significant, the share of electricity from fossil sources is positive and significant, electricity price has a negative and significant coefficient. Country dummies have the same significance as well as the green certificate dummy. The only difference is that solar photo-voltaic now display a significant and negative coefficient. So far, this first set of results confirms that incentives positively affect the production of directly incentivized renewable energy.

[INSERT TABLE 6 ABOUT HERE]

A related issue is whether the incentives increase total renewable energy production. We might expect that the impact is weaker, as most of hydropower energy produced is not incentivised. Results reported in Table 7 suggest that the amount of incentive is still significant in explaining total RES-E production. As concerns the other controls, they are generally not significant. The country dummies lose significance in comparison with the results previously discussed, while the source dummies instead are more significant. More precisely, we observe that total RES-E production, keeping bio-energy as a term of comparison, is statistically larger in hydropower and smaller in geothermal and solar PV industries. We notice that the green certificate dummy is not significant, suggesting that the type of instrument adopted does not affect the total production of renewable energy. Results in Table 8 show that the tariff does not significantly affect the total RES-E production. The combined result obtained in Tables 6 and 8 suggests that the level of tariff, while positively influencing the production of incentivized energy, is not relevant in determining the total

RES-E production. The other controls are poorly significant and convey the same message as in Table 7.

[INSERT TABLES 7 and 8 ABOUT HERE]

Finally, we consider whether the incentives have a permanent impact, in that they affect the total RES-E installed capacity. We find that incentives do significantly affect the RES-E installed capacity. More incentives positively influence the installed capacity, as reported in Table 9. The control variables are poorly significant, only the source dummies are significant at 1% level. With respect to bio-energy, we get a negative and significant coefficient for geothermal and solar PV, and a positive and significant coefficient for hydropower, as when considering total RES-E production. Interestingly, when considering installed capacity we also find a positive and significant coefficient for wind power.

[INSERT TABLE 9 ABOUT HERE]

Results are robust when adopting the alternative measure of support, namely the level of the tariff granted to RES-E. We get a positive and significant coefficient across different specifications, as reported in Table 10. As for the control variables, the results discussed in Table 9 are confirmed.

[INSERT TABLE 10 ABOUT HERE]

Overall, the analysis suggests that incentives have a positive impact on renewable energy production both in the short and in the long run. Indeed, they positively affect both the production of incentivized energy, in the short run, as well as the creation of installed capacity.

7. Conclusions

In this paper we investigate how monetary incentives to renewable energy affect the production of energy. We focus of five large European countries for the period 2000-2010 and we recover the amount granted from the official country reports. With this respect, we contribute to the literature, which generally adopts simpler measures to quantify these policies, while we collect information on the exact amount granted to each energy source, through the different instruments, which we classify into two broad groups: Feed-in Tariff or Green Certificates.

We test how these subsidies affected energy production both in a short and in a long run perspective. First, we investigate the impact on the incentivized RES-E production and total RES-E production, which reflect the immediate effect of these policies. Then, we regress the subsidy measures on total RES-E installed capacity. While an increase in energy production can, up to a certain extent, be accommodated without changing the capacity, an increase in installed capacity reflects a change that is not temporary, as it entails non-negligible fixed costs.

Our results suggest that these policies have been effective in promoting renewable energy, both in the short run, as we observe a positive relationship with the production of incentivized energy, and in the long run, as there is a positive relationship with the installed capacity. The type of policy instrument is also found to be significant, with Feed-in Tariff proving more effective than Green Certificates in the short run.

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Tables and Figures

Table 1 Explanatory variables adopted in the literature

Energy variables	
energy imports	Groba et al. (2011); Marques et al. (2010); Marques et al. (2011); Yin Powers (2010)
fossil sources prices (oil, natural gas, coal)	Marques et al. (2010); Marques et al. (2011); Shrimali Kniefel (2011)
CO2 emissions per capita	Delmas Montes-Sancho (2011); Marques et al. (2010); Marques et al. (2011)
energy consumption per capita	Carley (2009); Groba et al. (2011); Marques et al. (2010); Marques et al. (2011)
contribution of fossil fuels to electricity generation	Groba et al. (2011); Delmas Montes-Sancho (2011); Marques et al. (2010); Marques et al. (2011); Shrimali Kniefel (2011)
electricity price	Carley (2009); Delmas Montes-Sancho (2011); Shrimali Kniefel (2011); Yin Powers (2010)
percentage of GDP attributable to petroleum and coal products	Carley (2009)
market deregulation	Carley (2009); Delmas Montes-Sancho (2011);
Total customers/green residential customers	Delmas Montes-Sancho (2011)
Utilities' public ownership	Delmas Montes-Sancho (2011)
Economic variables	
GDP	Marques et al. (2010); Marques et al. (2011);
GDP per capita	Carley (2009); Delmas Montes-Sancho (2011); Groba et al. (2011); Shrimali Kniefel (2011); Yin Powers (2010)
tax incentives and subsidies	Carley (2009)
unemployment rate	Delmas Montes-Sancho (2011);
Geographic variables	
area	Groba et al. (2011); Marques et al. (2010); Marques et al. (2011)
renewable sources technical potential	Carley (2009); Delmas Montes-Sancho (2011); Menz Vachon (2006)
population growth	Carley (2009)
Political variables	
EU 2011 directive	Groba et al. (2011); Marques et al. (2010); Marques et al. (2011)
Government/Parliament political orientation	Carley (2009); Delmas Montes-Sancho (2011); Shrimali Kniefel (2011); Yin Powers (2010)
Employees in natural resources governmental positions (per capita)	Carley (2009)

Table 2 Dependent variables adopted in the literature

Variable	Reference	Source specification
Renewable Energy % of Total Primary Energy Supply	Marques et al. (2010)	all sources
	Marques et al. (2011)	all sources
Renewable Energy % of Total Energy Capacity	Shrimali Kniefel (2011)	all sources except hydro
	Yin Powers (2010)	all sources except hydro
Renewable Energy % of Electricity Generation	Carley (2009)	all sources except hydro
Renewable Energy generation	Carley (2009)	all sources except hydro
Added capacity, growth in capacity	Groba et al. (2011); Menz Vachon (2006)	onshore wind and solar PV
Installed capacity	Delmas Montes-Sancho (2011)	all sources
	Menz Vachon (2006)	wind

Table 3 Policies implemented

Country	Type of Policy	Name of Policy	Time period	Source of Data
France	FiT	Obbligation d'Achat	2002 - 2010	CRE
Germany	FiT	EEG	2000 - 2010	EEG
Italy	FiT	CIP 6	2001 - 2010	GSE
Italy	GC	Certificati Verdi	2002 - 2010	GSE
Italy	FiT	Conto Energia	2006 - 2010	GSE
Italy	FiT	Tariffa Onnicomprensiva	2009 - 2010	GSE
Spain	FiT	Regimen Especial	2000 - 2010	CNE
United Kingdom	GC	Renewable Obbligation	2002 - 2010	OFGEM
United Kingdom	FiT	FiT	2010	OFGEM

Table 4 Explanatory variables in the anaysis

	Variable Name	Label	Source	Unit	Sample
Dependent Variables	*incprod*	Incentivized RES-E production	EIA	MWh	2000 - 2010
	totprod	Total RES-E production	EIA	TWh	2000 - 2010
	totcap	Total RES-E installed capacity	EIA	MW	2000 - 2010
Explabatory Variables	*incent*	Amount of incentives	EIA	Thousands of €	2000 - 2010
	tariff	Tariff	EIA	€/MWh	2000 - 2010
Control Variables	*gdppc*	GDP per capita	WB	constant $ PPP 2005 for million of people	2000 - 2010
	co2pc	Per capita CO2 emissions for electricity production	EIA	Million metric tons for million of people	2000 - 2010
	fos	Share of electricity production from fossil sources	EIA	TWh	2000 - 2010
	netelexp	Net electricity exports	EIA	TWh	2000 - 2010
	elprice	Electricuty prices	EUROSTAT	€/MWh	2000 - 2010
	govparty	Cabinet composition (Schmidt-Index)	Codebook CPDSIII	scale	2000 - 2010

Table 5 Incentivized RES-E production and amount of incentives

	(1) OLS	(2) FE	(3) RE	(4) HT
$Incentive_{t-1}$	1.023***	0.372***	0.721***	0.376***
	(0.036)	(0.113)	(0.087)	(0.060)
GDP per $capita_{t-1}$	12.859**	11.912**	12.468***	11.926**
	(6.046)	(5.150)	(3.508)	(5.084)
CO_2 $emissions_{t-1}$	6.846	-0.018	3.672	0.024
	(8.547)	(3.304)	(3.926)	(7.971)
Share of electricity from fossil $sources_{t-1}$	0.770	14.590**	7.254	14.522
	(10.693)	(5.755)	(5.724)	(9.540)
Electricity net $export_{t-1}$	0.009	0.010	0.009	0.010
	(0.022)	(0.014)	(0.015)	(0.023)
Electricity $price_{t-1}$	-0.144***	-0.096***	-0.122***	-0.096***
	(0.025)	(0.023)	(0.025)	(0.015)
Left wing $government_{t-1}$	0.041	-0.064	-0.005	-0.063
	(0.182)	(0.115)	(0.074)	(0.132)
Germany	-4.209		-2.280	-0.009
	(3.291)		(2.174)	(4.634)
Italy	12.103***		12.710***	13.469***
	(3.405)		(2.819)	(4.301)
Spain	3.471		4.830***	6.406*
	(2.343)		(1.631)	(3.788)
Unitet Kingdom	-2.359		-2.029	-1.548
	(2.713)		(1.781)	(4.186)
Geothermal	-1.273**		-2.434**	-3.786
	(0.517)		(1.141)	(2.993)
Hydropower	0.222		0.170	0.111
	(0.530)		(1.290)	(2.983)
Solar PV	-0.656		-1.416	-2.286
	(0.452)		(1.015)	(2.987)
Wind Power	0.002		0.065	0.138
	(0.509)		(1.280)	(2.983)
Green certificate	-2.699***		-3.995***	-15.516***
	(0.411)		(1.009)	(3.791)
Constant	-307.729**	-289.371**	-295.681***	-284.482**
	(139.349)	(123.907)	(86.004)	(124.156)
Time Dummies	YES	YES	YES	YES
Observations	498	498	498	498
R^2	0.786	0.250		

Notes: Dependent variable is Incentivized energy. Robust standard errors are presented for OLS, FE and RE. *, **, *** significant at 10%, 5% and 1% respectively

Table 6 Incentivized RES-E production and tariff of incentives

	(1) OLS	(2) FE	(3) RE	(4) HT
$Tariff_{t-1}$	0.256***	0.184**	0.191**	0.185***
	(0.027)	(0.078)	(0.075)	(0.028)
GDP per $capita_{t-1}$	13.699	13.006*	13.068*	13.022**
	(10.757)	(6.871)	(6.917)	(5.074)
CO_2 $emissions_{t-1}$	2.319	0.563	0.724	0.592
	(13.829)	(4.034)	(4.049)	(7.951)
Share of electricity from fossil $sources_{t-1}$	12.846	15.470**	15.226**	15.435
	(17.537)	(6.792)	(6.788)	(9.485)
Electricity net $export_{t-1}$	0.013	0.013	0.013	0.013
	(0.041)	(0.017)	(0.017)	(0.023)
Electricity $price_{t-1}$	-0.107***	-0.096***	-0.097***	-0.096***
	(0.027)	(0.022)	(0.022)	(0.015)
Left wing $government_{t-1}$	-0.145	-0.142	-0.142	-0.141
	(0.246)	(0.154)	(0.155)	(0.132)
Germany	-0.790		0.058	0.124
	(6.129)		(2.932)	(4.154)
Italy	15.210***		15.001***	14.979***
	(5.798)		(2.652)	(3.784)
Spain	7.284*		7.504***	7.521**
	(4.405)		(2.279)	(3.184)
United Kingdom	-1.543		-1.376	-1.370
	(5.159)		(1.645)	(3.655)
Geothermal	-4.933***		-5.023**	-5.029**
	(0.704)		(2.007)	(2.189)
Hydropower	0.205		0.165	0.162
	(0.822)		(2.375)	(2.188)
Solar PV	-5.826***		-5.168**	-5.114**
	(0.766)		(2.114)	(2.206)
Wind Power	0.291		0.272	0.270
	(0.837)		(2.440)	(2.188)
Green certificate	-5.669***		-6.022***	-8.882**
	(0.536)		(1.429)	(3.653)
Constant	-326.473	-316.964*	-309.130*	-315.261**
	(256.258)	(163.817)	(164.162)	(123.923)
Time Dummies	YES	YES	YES	YES
Observations	498	498	498	498
R^2	0.503	0.26		

Notes: Dependent variable is Incentivized energy. Robust standard errors are presented for OLS, FE and RE. *, **, *** significant at 10%, 5% and 1% respectively

Table 7 Total RES-E production and amount of incentives

	(1) OLS	(2) FE	(3) RE	(4) HT
$Incentive_{t-1}$	0.026***	0.020	0.020*	0.020***
	(0.008)	(0.012)	(0.012)	(0.007)
GDP per $capita_{t-1}$	-0.676	-0.687	-0.686	-0.687
	(1.267)	(1.090)	(1.100)	(0.597)
CO_2 $emissions_{t-1}$	0.223	0.162	0.167	0.162
	(2.170)	(1.102)	(1.114)	(0.935)
Share of electricity from fossil $sources_{t-1}$	-2.283	-2.159*	-2.169*	-2.159*
	(2.265)	(1.127)	(1.136)	(1.116)
Electricity net $export_{t-1}$	0.002	0.002	0.002	0.002
	(0.006)	(0.004)	(0.004)	(0.003)
Electricity $price_{t-1}$	-0.002	-0.001	-0.001	-0.001
	(0.004)	(0.003)	(0.003)	(0.002)
Left wing $government_{t-1}$	-0.005	-0.006	-0.006	-0.006
	(0.036)	(0.027)	(0.027)	(0.016)
Germany	0.823		0.859	0.862*
	(0.960)		(0.606)	(0.502)
Italy	0.390		0.404	0.405
	(0.773)		(0.552)	(0.459)
Spain	-0.069		-0.044	-0.042
	(0.551)		(0.420)	(0.392)
United Kingdom	0.115		0.124	0.125
	(0.777)		(0.557)	(0.444)
Geothermal	-1.677***		-1.699***	-1.701***
	(0.101)		(0.288)	(0.283)
Hydropower	1.058***		1.058***	1.057***
	(0.098)		(0.295)	(0.281)
Solar PV	-1.623***		-1.636***	-1.638***
	(0.075)		(0.192)	(0.282)
Wind Power	-0.115		-0.114	-0.114
	(0.105)		(0.305)	(0.281)
Green certificate	0.109		0.086	-0.016
	(0.069)		(0.187)	(0.383)
Constant	19.286	19.384	20.102	19.601
	(31.220)	(26.687)	(26.835)	(14.566)
Time Dummies	YES	YES	YES	YES
Observations	500	500	500	500
R^2	0.747	0.398		

Notes: Dependent variable is Renewable energy production. Robust standard errors are presented for OLS, FE and RE. *, **, *** significant at 10%, 5% and 1% respectively

Table 8 Total RES-E production and tariff of incentives

VARIABLES	(1) OLS	(2) FE	(3) RE	(4) HT
$Tariff_{t-1}$	0.002	0.000	0.000	0.000
	(0.003)	(0.004)	(0.004)	(0.003)
GDP per $capita_{t-1}$	-0.702	-0.721	-0.719	-0.721
	(1.277)	(1.124)	(1.135)	(0.603)
CO_2 $emissions_{t-1}$	0.008	-0.040	-0.036	-0.040
	(2.208)	(1.097)	(1.109)	(0.944)
Share of electricity from fossil $sources_{t-1}$	-1.821	-1.748	-1.753	-1.748
	(2.282)	(1.095)	(1.105)	(1.123)
Electricity net $export_{t-1}$	0.002	0.002	0.002	0.002
	(0.006)	(0.004)	(0.004)	(0.003)
Electricity $price_{t-1}$	-0.000	0.000	0.000	0.000
	(0.004)	(0.003)	(0.003)	(0.002)
Left wing $government_{t-1}$	-0.010	-0.010	-0.010	-0.010
	(0.036)	(0.027)	(0.028)	(0.016)
Germany	0.967		0.992	0.993*
	(0.973)		(0.609)	(0.507)
Italy	0.462		0.456	0.456
	(0.774)		(0.558)	(0.463)
Spain	0.044		0.050	0.051
	(0.551)		(0.417)	(0.395)
United Kingdom	0.152		0.157	0.157
	(0.786)		(0.567)	(0.449)
Geothermal	-1.777***		-1.779***	-1.779***
	(0.095)		(0.290)	(0.285)
Hydropower	1.055***		1.054***	1.054***
	(0.097)		(0.293)	(0.285)
Solar PV	-1.709***		-1.691***	-1.689***
	(0.076)		(0.196)	(0.287)
Wind Power	-0.109		-0.109	-0.109
	(0.104)		(0.304)	(0.285)
Green certificate	0.012		0.002	-0.094
	(0.067)		(0.182)	(0.506)
Constant	19.917	20.224	20.954	20.445
	(31.486)	(27.492)	(27.664)	(14.720)
Time Dummies				
Observations	500	500	500	500
R^2	0.741	0.387		

Notes: Dependent variable is Renewable energy production. Robust standard errors are presented for OLS, FE and RE. *, **, *** significant at 10%, 5% and 1% respectively

Table 9 Total RES-E installed capacity and amount of incentives

VARIABLES	(1) OLS	(2) FE	(3) RE	(4) HT
$Incentive_{t-1}$	0.085***	0.067*	0.070*	0.067***
	(0.015)	(0.040)	(0.036)	(0.019)
GDP per $capita_{t-1}$	-3.831	-3.862	-3.858	-3.862**
	(2.458)	(2.868)	(2.897)	(1.599)
CO_2 $emissions_{t-1}$	-0.334	-0.513	-0.487	-0.513
	(4.434)	(1.847)	(1.863)	(2.504)
Electricity from fossil $fuel_{t-1}$	-1.283	-0.920	-0.974	-0.920
	(4.732)	(4.062)	(4.092)	(2.990)
Electricity net $export_{t-1}$	-0.006	-0.006	-0.006	-0.006
	(0.011)	(0.010)	(0.010)	(0.007)
Electricity $price_{t-1}$	-0.010	-0.009	-0.009	-0.009*
	(0.009)	(0.008)	(0.008)	(0.005)
Left wing $government_{t-1}$	-0.092	-0.095	-0.095	-0.095**
	(0.079)	(0.085)	(0.086)	(0.042)
Germany	3.083		3.181*	3.199**
	(1.933)		(1.804)	(1.251)
Italy	1.707		1.744	1.750
	(1.596)		(1.760)	(1.124)
Spain	-0.438		-0.369	-0.357
	(1.058)		(0.965)	(0.927)
United Kingdom	1.370		1.394	1.398
	(1.548)		(1.557)	(1.082)
Geothermal	-4.637***		-4.696***	-4.706***
	(0.266)		(0.687)	(0.572)
Hydropower	2.934***		2.932***	2.931***
	(0.186)		(0.433)	(0.567)
Solar PV	-1.548***		-1.585***	-1.592***
	(0.209)		(0.447)	(0.569)
Wind Power	1.594***		1.597***	1.598***
	(0.171)		(0.420)	(0.567)
Green certificate	0.359**		0.297	-0.007
	(0.150)		(0.396)	(0.802)
Constant	98.348	100.108	101.021	99.267**
	(59.958)	(69.487)	(69.726)	(39.026)
Time Dummies	YES	YES	YES	YES
Observations	500	500	500	500
R^2	0.811	0.424		

Notes: Dependent variable is Renewable installed capacity. Robust standard errors are presented for OLS, FE and RE. *, **, *** significant at 10%, 5% and 1% respectively

Table 10 Total RES-E installed capacity and tariff of incentives

VARIABLES	(1) OLS	(2) FE	(3) RE	(4) HT
$Tariff_{t-1}$	0.037***	0.034*	0.034**	0.034***
	(0.009)	(0.018)	(0.017)	(0.009)
GDP per $capita_{t-1}$	-3.627	-3.655	-3.652	-3.655**
	(2.346)	(2.820)	(2.849)	(1.597)
CO_2 $emissions_{t-1}$	-0.323	-0.393	-0.385	-0.393
	(4.509)	(1.793)	(1.807)	(2.499)
Electricity from fossil $fuel_{t-1}$	-0.863	-0.756	-0.768	-0.756
	(4.769)	(4.054)	(4.082)	(2.973)
Electricity net $export_{t-1}$	-0.006	-0.006	-0.006	-0.006
	(0.011)	(0.010)	(0.010)	(0.007)
Electricity $price_{t-1}$	-0.009	-0.009	-0.009	-0.009*
	(0.009)	(0.008)	(0.008)	(0.005)
Left wing $government_{t-1}$	-0.109	-0.109	-0.109	-0.109***
	(0.079)	(0.084)	(0.085)	(0.041)
Germany	3.174		3.207*	3.212**
	(1.960)		(1.788)	(1.249)
Italy	2.030		2.023	2.022*
	(1.591)		(1.773)	(1.124)
Spain	-0.169		-0.160	-0.158
	(1.038)		(0.943)	(0.924)
United Kingdom	1.415		1.421	1.422
	(1.550)		(1.549)	(1.082)
Geothermal	-4.923***		-4.926***	-4.927***
	(0.249)		(0.703)	(0.571)
Hydropower	2.942***		2.941***	2.941***
	(0.177)		(0.412)	(0.571)
Solar PV	-2.133***		-2.107***	-2.103***
	(0.224)		(0.482)	(0.578)
Wind Power	1.623***		1.622***	1.622***
	(0.166)		(0.408)	(0.571)
Green certificate	0.199		0.185	0.045
	(0.139)		(0.374)	(1.041)
Constant	93.262	94.859	96.045	94.030**
	(57.608)	(68.380)	(68.658)	(38.978)
Time Dummies	YES	YES	YES	YES
Observations	500	500	500	500
R^2	0.807	0.427		

Notes: Dependent variable is Renewable installed capacity. Robust standard errors are presented for OLS, FE and RE. *, **, *** significant at 10%, 5% and 1% respectively

Figure 1

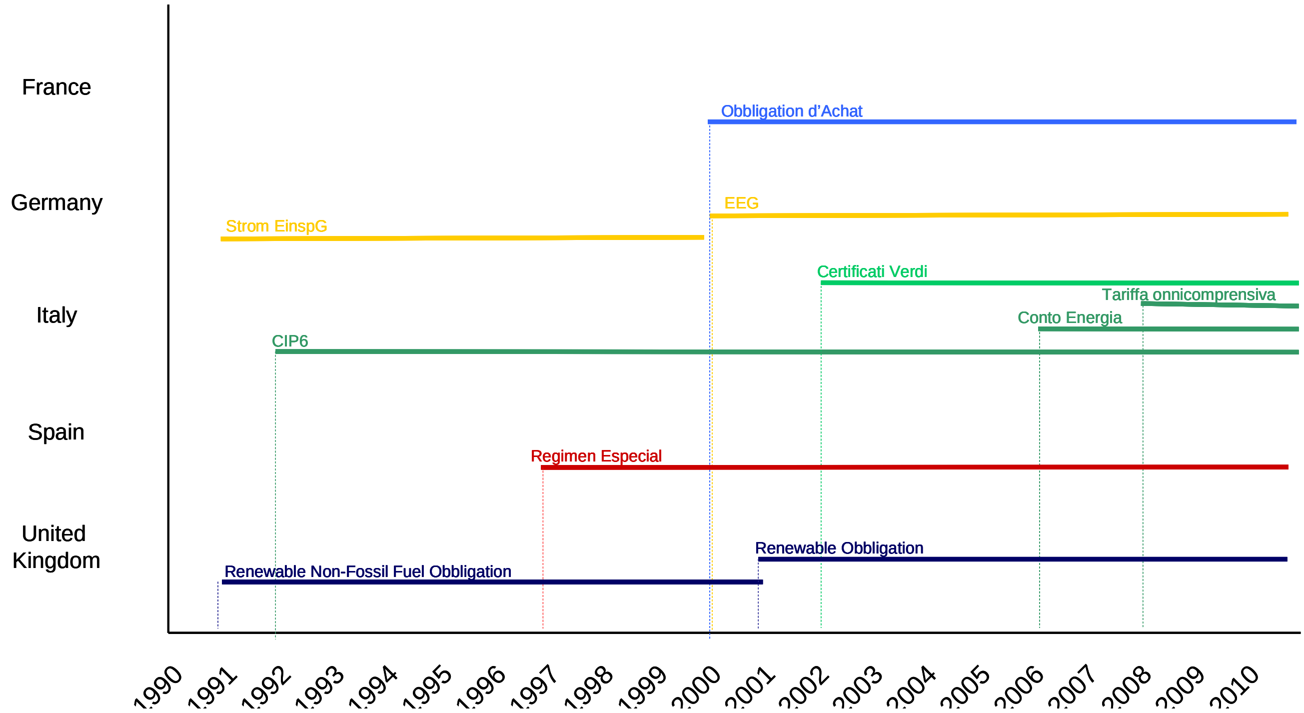

Figure 2 Total amount of incentives granted yearly

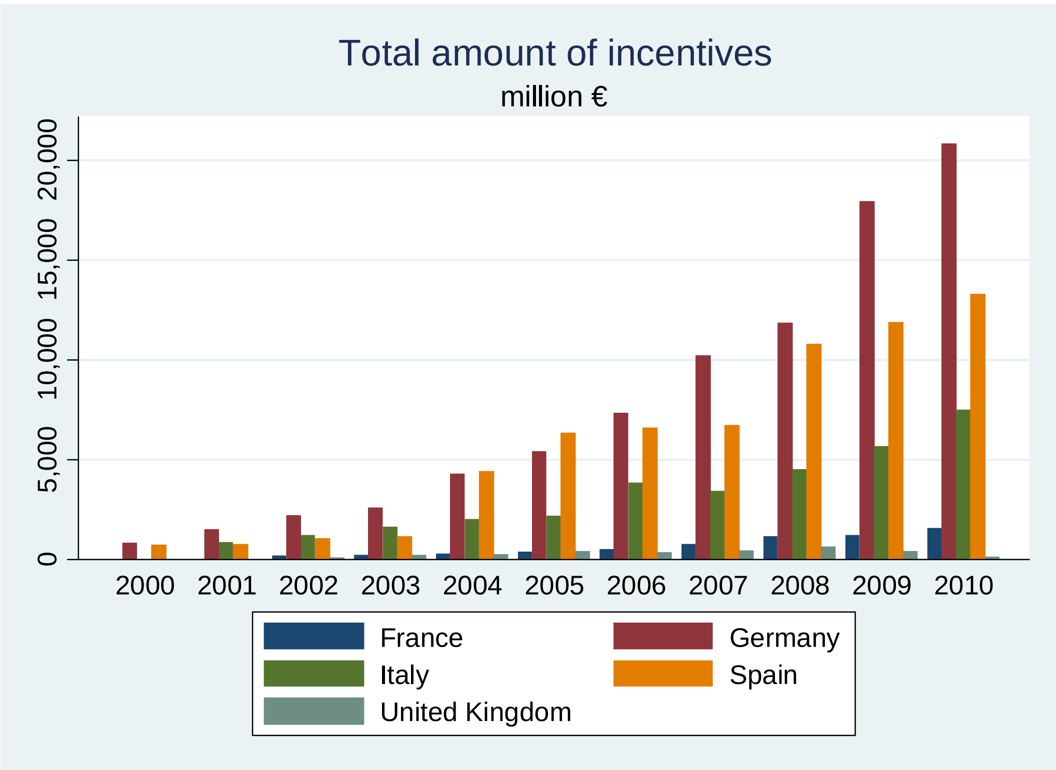

Figure 3: Average tariff across different sources