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Energy Sustainability

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ABSTRACT: Policy combinations and interactions have received a considerable attention in the energy policy realm. The aim of our working paper is to provide insight on the cost-effectiveness of combinations of deployment instruments for the same technology. A financial model is developed for this purpose, whereby feed-in tariffs (FITs) and premiums (FIPs) are combined with investment subsidies and soft loans. The results show that combining deployment instruments is not a cost-containment strategy. However, combinations may lead to different inter-temporal distributions of the same amount of policy costs which can affect the social acceptability and political feasibility of renewable energy support.

JEL Codes: H81, L51, Q48

Keywords: Renewable energy, policies, combinations, cost-effectiveness, feed-in tariffs

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1. Introduction.

The economics literature has paid attention to the analysis of policy combinations in the climate and energy policy realms. Following the well-known principle in economics that a single market failure is best addressed with one instrument, while multiple market failures require multiple instruments (Tinbergen 1952, del Río 2009, Fischer and Preonas 2010), the literature generally argues that we need to combine several instruments. The scope of such combinations clearly depends on the externalities to be addressed and, in short, on the technical maturity and commercial competitiveness of the energy technologies in general and renewable energy technologies (RETs) in particular. For example, while R&D support is critical in the first stages of the innovation process (basic and applied R&D), its relevance comparatively diminishes as we advance to the pre-commercial stages. It becomes relatively unimportant for fully commercial technologies characterised by a dominant design. In contrast, a carbon price is useful to internalize the negative environmental externality, which is the most relevant in the last stages of the innovation process.

Deployment support has generally been justified for intermediate stages. Although there is a wide agreement that combinations may be needed to tackle the market failures, it has also been shown that them could lead to conflicts, resulting in inefficiencies, redundancies, double coverage or double counting (Sorrel and Sijm 2003, del Río 2007). This empirical finding has led many to be sceptical about instrument combinations. This paper focuses on the interaction mechanism of instrument combinations to support the deployment of electricity from renewable energy sources (RES-E), analysing whether such combination is either redundant or cost-effective with respect to the use of a single instrument.

There are several RES-E deployment instruments, which generally fall in two groups: primary instruments (feed-in tariffs (FITs), feed-in premiums (FIPs), quotas with tradable green certificates (TGCs) and tendering schemes) and secondary instruments (investment subsidies, fiscal incentives and soft loans, among others) (see section 2). However, the abundant literature comparing the primary instruments between them (see, among others, Ragwitz et al 2007, del Rio and Gual 2004 and Finon and Perez 2007) contrasts with the scarce research on their detailed interactions.

Virtually no attention has been paid to the combination of deployment instruments for the same technology, not even in recent, highly influential policy documents such as the policy chapter in the IPPC Report on Climate Change and Renewables (Mitchell et al 2011) and the IEA Report on Policies for Renewables (Müller et al 2011)[1]. This neglect is all the more striking given the existence of combinations of deployment instruments either for the same technology or across technologies in the real world (REN21 2005 and 2009). What RES-E support policies to use and, therefore, how to combine them in order to promote the deployment of RES-E cost-effectively is a relevant issue for governments, at least in the EU, where ambitious targets for the penetration of renewable energy in energy consumption have been set for 2020 (Directive 28/2009/EC).

Therefore, the question remains whether combining primary and secondary deployment instruments leads to better results in terms of cost-effectiveness compared to their separate use, i.e., whether the same amount of RES-E can be deployed at a lower costs for consumers. We try to contribute to the extremely thin literature on the topic with the help of a financial model. The aim of this paper is twofold. First, we test how FITs and FIPs are modified if combined with investment subsidies or soft loans. The second, related aim is to test whether a combination of these primary and secondary deployment instruments leads to lower support costs compared to the use of FITs or FIPSs alone (for the same amount of RES-E deployment).

Accordingly, the paper is structured as follows. The next section provides a description of RES-E support schemes and identifies combinations of those deployment instruments, with a focus on the European context. Sections 3 and 4 discuss the relationship between FITs and FIPs, and investment subsidies and soft loans when the net benefit for the investor is constant (section 3) and when the net benefit and the discount rate are reduced (section 4). The support costs of policy combinations are analysed in section 5. Section 6 concludes.

[1] Indeed, Mitchell et al (2011) note that further research is also needed to fully understand the effectiveness and efficiency of combinations of policy instruments designed to achieve a very high share of RES-E in the long term.

2. Primary and secondary RES-E support schemes and their combinations.

RES-E deployment promotion has traditionally been based on four main (primary) support measures, whose costs are usually borne by consumers: FITs, FIPs, quotas with TGCs and tendering (see del Río and Gual 2004, Huber et al 2004, Ragwitz et al 2007, Ragwitz et al 2012, Teckenbourg et al 2011, Klessmann and Lovinfosse, 2012, and IEA/IRENA 2013 for further details).

- *Feed-in laws* are preferential prices per kWh (or MWh) generated, which are combined with a purchase obligation by the utilities. The most relevant distinction is between feed-in tariffs (FITs) and premium systems (FIPs). The former provides total payments per kWh of electricity of renewable origin while, in the later case, a payment per kWh on top of the electricity wholesale-market price is granted (Sijm 2005). Both types are applied in 19 EU countries.
- *TGCs* are certificates that can be sold in the market, allowing RES-E generators to obtain revenue. This is additional to the revenue from their sales of electricity fed into the grid. Therefore, RES-E generators benefit from two streams of revenue from two different markets: the market price of electricity plus the market price of TGCs multiplied by the number of MWh of renewable electricity fed into the grid. The issuing (supply) of TGCs takes place for every MWh of RES-E, while demand generally originates from an obligation. Electricity distribution companies must surrender a number of TGCs as a share of their annual consumption or pay a penalty. The TGC price covers the gap between the marginal cost of renewable electricity generation at the quota level and the price of electricity. Quotas with TGCs are used in 6 EU countries (U.K., Sweden, Belgium, Italy, Romania and Poland), with two of them partially using FITs (Italy and U.K.).
- *Tendering*. The government invites RES-E generators to compete for either a certain financial budget or a certain RES-E generation capacity. Within each technology band the cheapest bids per kWh are awarded contracts and receive the subsidy. The operator pays the bid price per kWh. In the EU, tendering is currently used in Lithuania and in the Netherlands, UK and Denmark for off-shore wind. In the past, it was also used in Ireland (AER)(1995-2003), U.K. (NFFO)(1990-1998), France (EOLE 1996) (PPI, 1996-2004 for wind, 2000-2007 for biomass), Latvia (2006-2009) and Portugal (2005-2008). It was implemented in Italy in 2013.

In addition to these primary instruments, there are several secondary instruments which have been combined with the former in the past:

- *Investment subsidies.* They are granted in the beginning of the project lifetime and can be calculated as a percentage of the renewable energy output or the specific investment cost, although this latter version is more common. Investments grants for RES-E are available in several Member States. Investment subsidies are applied for most renewable energy technologies in the Czech Republic, Finland, Cyprus, Greece, the Netherlands, Hungary, Lithuania and Latvia. They are applied in Belgium, Luxembourg, Malta and the Netherlands for solar PV.
- *Fiscal incentives* can be exemptions or rebates on (energy, corporate or income) taxes, tax refunds, lower VAT rates or attractive depreciation schemes. Some countries, including Spain, the Netherlands, Finland and Greece provide tax incentives related to investments (including income tax deductions or credits for some fraction of the capital investment made in renewable energy projects, or accelerated depreciation). Other Member States, including Latvia, Poland, Slovakia, Sweden and the UK, provide income tax deductions or credits at a set rate per unit of RES-E (de Jager et al 2011).
- *Soft loans* are usually provided by governments with a rate below the market interest rate. In some cases, they can significantly reduce the costs of capital. Soft loans may also provide longer repayment periods or interest holidays. Soft-loans are available in Bulgaria, Germany, Estonia, Malta, Poland, the Czech Republic, Hungary, Lithuania, the Netherlands (except for offshore wind) and Slovenia.

Combinations of FITs and FIPs with either investment subsidies or soft loans (the focus of this paper), for the same technologies, have been implemented in several countries, according to BMU

(2011) and Wrinkel et al (2011)[2]. For example, FITs are used jointly with investment subsidies in Austria, Cyprus, the Czech Republic, Denmark (for small installations), Finland, Greece, Hungary, Lithuania (only for rooftop solar PV and for RES-E used in enterprises), Luxembourg (for the installation of solar systems in private households and RES-E investments in companies), Malta (only for small solar installations), Portugal, Slovakia and Slovenia.

The combination of FITs and soft loans seems to be more common in the renewable heating than in the renewable electricity sector (see Wrinkler et al 2011). FITs and soft loans have jointly been used to support RES-E in Bulgaria, the Czech Republic, Germany, Hungary, Lithuania, Malta, the Netherlands (not for offshore wind) and Slovenia.

With respect FIPs, they are combined with investment subsidies in Estonia, Finland and Slovakia and Slovenia, and with soft loans in the Netherlands.

While FITs and FIPs provide a stable revenue flow for investors, and have proven very effective at triggering RES-E investments, investment subsidies and soft loans may further encourage investments by reducing the costs of financing[3]. From the point of view of the payer, the value of the grant or the loan is known and does not create, at least in principle, any future liabilities. They may be particularly suitable for immature and higher risks technologies such as wind offshore or CSP compared to more mature technologies[4]. They are also relatively easy to administer, especially if an administration used to handle subsidy schemes is already operational[5]. However, from the point of view of the recipient, one of the well-known weaknesses of investment subsidies is their stop-and-go: they usually depend directly on the public budget and, therefore, alter with a changing political agenda (IEA 2011, Mitchell et al 2011).

3. The mechanism of instrument combinations.

A financial model has been built in three steps in order to provide an economic analysis of the combinations of FITs and FIPs with investment subsidies and soft loans. In the first step, the well-known expression of the net present value (V) of an investment project has been adapted to the specificities of the mix of deployment instruments. The expression of the V of a RES-E installation can be written as:

$$V = \sum_{t=1}^{t=T} \frac{p(1+\varepsilon)^t q_{AC_t}}{(1+i)^t} - \left[I + \sum_{t=1}^{t=T} \frac{m(1+\mu)^t}{(1+i)^t} \right] \qquad [1]$$

where,

q_{AC_t}	annual plant production (kWh or MWh)
I	upfront investments which includes the costs of the main equipments (i.e., turbines or PV panels) and their transportation to the site and installation, as well as the grid connection (cables, substation), civil works (foundations, roads, buildings) and many other costs (engineering, licensing, permitting, environmental assessments, consultancy, structuring finance and so on) (Wiser et al 2011, de Jager et al 2011)
t	time (a year), $t \in [1, T]$
T	installation lifetime
p	initial FIT level
m	initial O&M costs, expected expenditures for fuel (only for biomass), insurance, taxes, fees for energy commercialization and forecasting services.

[2] Investment subsidies and soft loans have also been combined with TGC schemes. This has been the case for investment subsidies in Flanders, Romania and Sweden (for solar PV and wind). Low-interest loans for renewable electricity generation are combined with a TGC scheme in Poland.

[3] They have a favourable impact on the debt/equity structure under the same debt service requirements (de Jager et al 2011).

[4] These latter have lower difficulties in finding loans since their risks are lower given that a great amount of experience already exists.

[5] But while a grant may help get a facility built without post-installation follow up, it does not ensure that a project will operate. Grants generally require oversight to ensure that certain preconditions are met, that the quality of new generating capacity meets at least a minimum standard, and that effective operation of installed systems is achieved. This implies additional administrative costs (Connor et al., 2009).

i interest rate (or discount rate)

ε annual rate of tariff revision.

μ annual rate of O&M costs increase.

All terms are defined in relation to the capacity of the plant (kW).

For the sake of simplicity, we assume that:

1. The upfront investment is paid cash, except otherwise stated.
2. The discount rate (i) is greater than the tariff revision rate (ε) and the annual rate of O&M costs increase (μ), that is, $i > \varepsilon = \mu$.
3. Annual production is constant: $q_{AC_t} = q$.
4. The initial O&M cost (m) is set as a proportion of the amount of investment: $m = \tau I$, $0 < \tau < 1$.
5. Taxes are not included.
6. The installation has no residual value.

Some remarks should be made with respect to assumption 2. On the one hand, the assumption $\mu = \varepsilon$ is easy to accept. Indeed, wages are an important part of O&M costs. Moreover, wages are annually revised according to the Consumer Price Index which is also the reference value used by several countries to update the FITs for the operating plants. Therefore, we assume that the dynamics of O&M costs and the rate of tariff updating overlap. On the other hand, the discount rate depends on the real interest rate of short-term public debt (i.e., the *minimum* interest rate), the inflation rate and the risk premium. It reflects the *gross* profitability expected by the investors. In this sense, it is associated to the cost of capital, i.e., the Weighted Average Cost of Capital (WACC).[6] The WACC could be understood as the required rate at which a prospective investor is prone to invest in a new plant (de Jager et al, 2011). For the purposes of our model, it is enough to assume that i will be greater than ε.

Starting from [1], the next step is to define the *profitability index* of the project, also called the profit investment ratio (r),

$$r = \frac{V}{I} \qquad [2]$$

Given the assumptions and rearranging the terms, we obtain the following equation,

$$r = \left(\frac{pq}{I} - \tau\right) \sum_{t=1}^{t=T} \left(\frac{1+\varepsilon}{1+i}\right)^t - 1 \qquad [3]$$

The finite series of this expression can be aggregated as follows,

$$\sum_{i=1}^{i=T} \left(\frac{1+\varepsilon}{1+i}\right)^t = \frac{1+\varepsilon}{i-\varepsilon}\left[1 - \left(\frac{1+\varepsilon}{1+i}\right)^T\right]$$

A positive number results because $i > \varepsilon$ (or $i = \alpha \cdot \varepsilon$, $\alpha > 1$) and the last term is lower than 1. If this sum is denoted by K, [2] can finally be rewritten as

$$r = K\left(\frac{pq}{I} - \tau\right) - 1 \qquad [4]$$

r allows us to quantify the present value of the *net* cash-flows with respect the upfront investments. The profitability index is commonly used for ranking investment projects which have a given expectation of revenues and outlays. The higher the profit investment ratio, the more desirable is the investment.[7]

All these expressions have been defined considering FITs. However, the kWh could be remunerated according to the wholesale electricity market price plus a premium, that is, by feed-in premium (FIP). It is not difficult to include FIP in such financial model. The general expression of FIP is given by,

$$\rho_t = e_t + \sigma_t$$

[6] As it is known, this criterion determines the required rate of return on a project. It combines the expected returns of equity holders (using the Capital Asset Pricing Model (CAPM)), with the requirement of lenders and reflects the investor's systematic and non-diversifiable risk. In the case of RES-E investments supported by FITs, two kinds of risks are considered: uncertainty on future electricity generation due to unexpected production breaks, technical problems, etc., which can cause additional O&M expenditures, and regulatory risk, i.e., the reductions of future revenues caused by changes in the support scheme.

[7] The model has not been designed to deal with other types of profitability indicators, such as the return on invested capital or the return on equity.

where,

ρ_t	guaranteed price for feeding-in (per kWh or MWh)
e_t	electricity wholesale market price
σ_t	premium

As expected, $\rho_t \leq p_t$ being p_t the FIT when RES-E generation costs are well above the retail and wholesale electricity prices.

In the expression of the net present value with FITs, we have considered the initial remuneration level (tariff) and its annual updating. In the case of remuneration through a premium, there is not such an updating of the support level. This requires that additional assumptions are made. The premium is added to the wholesale price of electricity. This premium may be set as a fixed amount, a percentage of such wholesale price or a changing quantity. This sliding premium fluctuates according to the pool price, with a floor payment and a cap payment. In order to simplify, we assume that investors analyze the past dynamics of the pool price and the associated premiums and that they interpolate these values into the future in order to calculate plausible profitability levels for their projects. Thus, we assume constant values for e and σ. If these assumptions were not made, the mathematical formulation would be complicated, although nothing substantial would be modified.

According to expressions [1] and [2], including ρ and taking into account the assumptions and rearranging the terms, we obtain

$$r = \left[\frac{(e+\sigma)q}{I}\right]\sum_{t=1}^{t=T}\frac{1}{(1+i)^t} - \left[\tau\sum_{t=1}^{t=T}\left(\frac{1+\epsilon}{1+i}\right)^t + 1\right]$$

The result of the first finite sum,

$$\sum_{t=1}^{t=T}\frac{1}{(1+i)^t} = \frac{(1+i)^T - 1}{i(1+i)^T}$$

will be denoted by Z.

Therefore,

$$r = \frac{(e+\sigma)q}{I}Z - (\tau K + 1) \qquad [5]$$

The third step is to appropriately modify expression [1] in order to include the different combinations of deployment instruments (investment subsidies and soft loans). Using these expressions, two main aspects will be studied:

1. How a given change in the level of investment subsidies or soft loans modifies the tariffs.
2. The cost of the policy combinations for consumers and/or the public budget with respect to the alternative (i.e., no instrument combinations).

3.1. Tariffs and premiums and investment subsidies.

Let I be the upfront investments of a given RES-E project. This amount is divided in two parts:

$$I = \gamma I + (1-\gamma)I, \; 0 < \gamma \leq 1$$

The term γI represents the amount of the investment subsidy and $(1-\gamma)I$ refers to the portion of the initial outlays which are financed by the promoters' own funds. Therefore, equation [1] can be rewritten as follows,

$$V = pq\sum_{t=1}^{t=T}\left(\frac{1+\varepsilon}{1+i}\right)^t + \gamma I - \left[\gamma I + (1-\gamma)I + \tau I\sum_{t=1}^{t=T}\left(\frac{1+\varepsilon}{1+i}\right)^t\right]$$

Promoters pay the upfront investments and, by assumption, the subsidy (γI) is granted before the plant operation begins. Rearranging the elements,

$$V = (pq - \tau I)\sum_{t=1}^{t=T}\left(\frac{1+\varepsilon}{1+i}\right)^t - I(1-\gamma) \qquad [6]$$

As it was established, the sum of the finite series is denoted by K. Therefore, this equation can be rewritten as,

$$V = pqK + I(\gamma - \tau K - 1)$$

According to the aforementioned definition of the profitability index,

$$r = \frac{V}{I} = \frac{pqK + I(\gamma - \tau K - 1)}{I}$$

To obtain the relationship between p and γ (i.e., the p=f(γ) function), we set $r=r^*$. Then,

$$p = \frac{I(r^* + 1 + \tau K)}{qK} - \frac{I}{qK}\gamma \qquad [7]$$

This is a decreasing straight line. Indeed, differentiating it with respect to γ, leads to

$$\frac{dp}{d\gamma} = -\frac{I}{qK}$$

which is a negative value.

In case of the combination of FIP and investment subsidies from the appropriate version of equation [1] it is obtained,

$$V = (e + \sigma)qZ + \gamma I - [\gamma I + (1 - \gamma)I + \tau IK]$$

Therefore, according to the aforementioned definition of the profitability index,

$$r = \frac{V}{I} = \frac{(e + \sigma)qZ + I(\gamma - \tau K - 1)}{I}$$

To obtain the relationship between the premium (σ) and γ (i.e., the σ=f(γ) function), we set $r=r^*$. Then,

$$\sigma = \frac{I(r^* + 1 + \tau K)}{qZ} - e - \frac{I}{qZ}\gamma \qquad [8]$$

This is a decreasing straight line. Indeed, differentiating it with respect to γ, leads to

$$\frac{d\sigma}{d\gamma} = -\frac{I}{qZ}$$

which is also a negative value. Moreover, from expression [8], the higher the pool price, the closer is the function σ=f(γ) to the origin. Therefore, the same level of subsidies can be combined with lower premium levels.

The main differences between [7] and [8] are the wholesale market price (e) and the factor Z in the denominator. The figure 1 illustrates the p=f(γ) and σ=f(γ) relationships. The data set refers to a photovoltaic plant, where: I=3,500 €/kW; T=30 years; q=1,800 kWh/kW; i=0.06; ε=0.02; r^*=0.04, τ=0.01 and e=0.05 €/kWh. In case of FIT the maximum value of the tariff is p_m=0.135 €/kWh and the minimum is p_n=0.024 €/kWh. This minimum value covers the O&M costs and ensures that the established net rate of return is achieved. In case of FIP, the maximum premium is σ_m=0.122 €/kWh and the minimum is σ_n=0 €/kWh, that is, when the project is subsidized up to the 86% of the upfront investment.

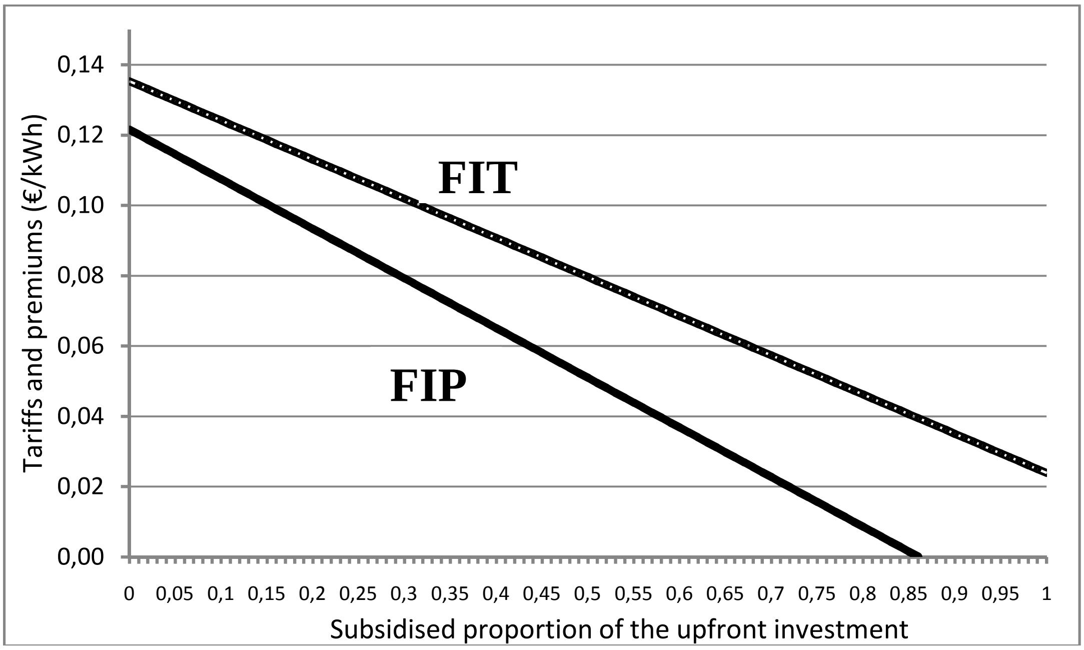

Figure 1. Tariffs (FIT) and premiums (FIP), and investment subsidies
Source: Own elaboration.

As it can be observed in the figure, the different values of the premium associated to a given subsidy level are below the remuneration level with tariffs. The reason is that the amount of the premium is, by definition, lower than the hypothetical reference tariff, given that RES-E generators receive the whole electricity price on top of the premium. Therefore, the *direct* financial burden on consumers is lower. If subsidies are added to the premium, for a given profitability level, there is a value of γ for which σ=0, that is,

$$\gamma' = r^* + 1 + \tau K - \frac{eqZ}{I}$$

Above such subsidy rate, the addition of the wholesale price and the premium would lead to an excessive remuneration of the projects. To avoid this, the premium has to be removed.

3.2. Tariffs and premiums, and soft loans

Let I be the amount of upfront investments which can be disaggregated in two parts:

$$I = \lambda I + (1-\lambda)I,\ 0<\lambda\leq 1$$

The term λI refers to the portion of the investment which is financed by a soft loan and $(1-\lambda)I$ represents the part paid in cash by the investors. As a rule, shareholders get access to advantageous debt conditions only if they finance the remaining investment from their own funds. Hence, it could be assumed that investors do not finance any portion of the investment through commercial loans. Then, the appropriate expression of the net present value in order to calculate the relationship between tariffs and soft loans is:

$$V = \sum_{t=1}^{t=T} \frac{p(1+\varepsilon)^t q_{AC_t}}{(1+i)^t} - \left[(1-\lambda)I + \sum_{t=1}^{t=T} \frac{m(1+\mu)^t}{(1+i)^t} + \sum_{t=1}^{t=T} \frac{\lambda I}{T(1+i)^t} + \sum_{t=1}^{t=T} \frac{\lambda I\left(1-\frac{t-1}{T}\right)i^*}{(1+i)^t}\right] \quad [9]$$

For the sake of simplicity, the following specific assumptions are added:

1. The amortisation period is the same as the lifetime of the installation (T).
2. Amortisation consists of constant payoffs.[8] The debt service (payoffs plus interests) in the t-th period is:

[8] A constant payoffs amortisation schedule has been chosen instead of a constant annuities one, because of the mathematical complexity of the later (see Luderer et al 2002, p.39).

$$\lambda I\left[\frac{1}{T}+\left(1-\frac{t-1}{T}\right)i^*\right]$$

where λI represents the amount of the soft loan ($i^*=\varphi i$, $0\leq\varphi<1$),

Expression [9] can then be rewritten as follows,

$$V=pq\sum_{t=1}^{t=T}\frac{(1+\varepsilon)^t}{(1+i)^t}-(1-\lambda)I-\tau I\sum_{t=1}^{t=T}\frac{(1+\varepsilon)^t}{(1+i)^t}-\lambda\frac{1}{T}\sum_{t=1}^{t=T}\frac{1}{(1+i)^t}-\lambda I\varphi i\sum_{t=1}^{t=T}\left(1-\frac{t-1}{T}\right)\frac{1}{(1+i)^t}$$

Then,

$$pq\sum_{t=1}^{t=T}\frac{(1+\varepsilon)^t}{(1+i)^t}-\tau I\sum_{t=1}^{t=T}\frac{(1+\varepsilon)^t}{(1+i)^t}=(pq-\tau I)\frac{1+\varepsilon}{i-\varepsilon}\left[1-\left(\frac{1+\varepsilon}{1+i}\right)^T\right]$$

that is,

$$(pq\text{-}\tau I)K$$

If we consider the factors associated to the loan amortisation, i.e.,

$$\lambda I\frac{1}{T}\sum_{t=1}^{t=T}\frac{1}{(1+i)^t}+\lambda I\varphi i\left[\sum_{t=1}^{t=T}\left(1-\frac{t-1}{T}\right)\frac{1}{(1+i)^t}\right] \qquad [10]$$

whereas the first finite sum has been denoted by Z, the second one can be written as,

$$\frac{(1+i)^{-T}}{i^2T}-\frac{1}{i^2T}+\frac{1}{i}$$

If this result is denoted by W, then expression [10] becomes,[9]

$$\lambda IZ\frac{1}{T}+\lambda IW\varphi i$$

Therefore, equation [9] can be transformed into,

$$V=(pq-\tau I)K-(1-\lambda)I-\lambda Z\frac{I}{T}-\lambda IW\varphi i \qquad [11]$$

Then, the relationship between p, λ and φ, after setting up $r=r^*$, can be written as follows:

$$p=\frac{I\left[(1-\lambda)+\tau K+r^*+\lambda Z\frac{1}{T}+\lambda Wi\varphi\right]}{qK} \qquad [12]$$

Equation [12] has two degrees of freedom (λ and φ). For that reason, it can be analysed from two different perspectives:

1. The impact of λ on p, i.e., how changes in the share of the upfront investments which can be paid by a soft loan (a percentage established by law), affect the tariff.
2. The impact of a reduction of the interest rate ($0\leq\varphi<1$) on tariffs, given a specific λ^*.

From [12], the p=f(λ) function can be written as follows,

$$p=\frac{I(1+\tau K+r^*)}{qK}+\frac{I\left(Wi\varphi^*+Z\frac{1}{T}-1\right)}{qK}\lambda \qquad [13]$$

and p=f(φ),

$$p=\frac{I\left[(1-\lambda^*)+\tau K+r^*+\lambda^*Z\frac{1}{T}\right]}{qK}+\frac{\lambda^*IWi}{qK}\varphi \qquad [14]$$

To start with the case of FIP combined with soft loans, the expression of the net present value now is,

$$V=\sum_{t=1}^{t=T}\frac{(e+\sigma)q_{AC_t}}{(1+i)^t}-\left[(1-\lambda)I+\sum_{t=1}^{t=T}\frac{m(1+\varepsilon)^t}{(1+i)^t}+\sum_{t=1}^{t=T}\frac{\lambda I}{T(1+i)^t}+\sum_{t=1}^{t=T}\frac{\lambda I\left(1-\frac{t-1}{T}\right)i^*}{(1+i)^t}\right] \qquad [15]$$

This expression can be rewritten as follows,

[9] $K>Z$ because the numerator ($1+\varepsilon$) in K is greater than 1, that is, when $\varepsilon>0$. However, $Z=K$ if $\varepsilon=0$.

$$V = (e+\sigma)qZ - \tau IK - (1-\lambda)I - \lambda Z\frac{I}{T} - \lambda IW\varphi i$$

Therefore, the relationship between σ, λ and φ, after setting up $r=r^*$, can be written as follows:

$$\sigma = \frac{I\left[(1-\lambda) + \tau K + r^* + \lambda Z\frac{1}{T} + \lambda Wi\varphi\right]}{qZ} - e \qquad [16]$$

Analogously to the FIT case, this equation has also two degrees of freedom (λ and φ). The σ=f(λ) function is,

$$\sigma = \frac{I(1+\tau K + r^*)}{qZ} - e + \frac{I\left(Wi\varphi^* + Z\frac{1}{T} - 1\right)}{qZ}\lambda \qquad [17]$$

and σ=f(φ),

$$\sigma = \frac{I\left[(1-\lambda^*) + \tau K + r^* + \lambda^* Z\frac{1}{T}\right]}{qZ} - e + \frac{\lambda^* IWi}{qZ}\varphi \qquad [18]$$

Figure 2 illustrates the p=f(λ) and σ=f(λ) functions[10]. As expected, the value of tariffs and premiums decrease when λ increases towards its maximum value (λ=1), that is, to the situation in which the whole upfront investment is financed by a soft loan. In case of FIT the maximum value of the tariff is p_m=0.135 €/kWh and the minimum is p_n=0.105 €/kWh. In case of FIP, the maximum premium is σ_m=0.122 €/kWh and the minimum is σ_n=0.083 €/kWh,

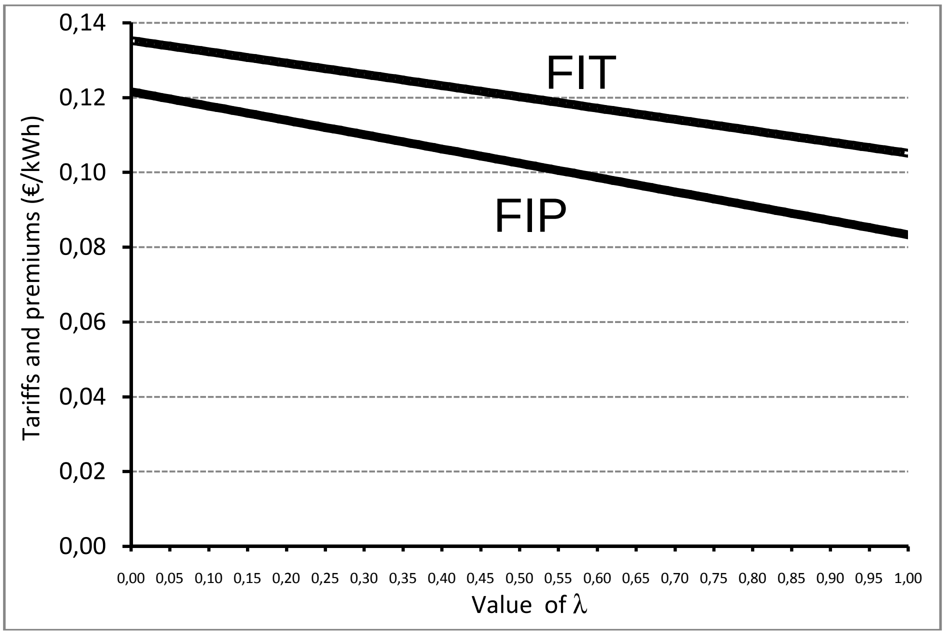

Figure 2. The relationship between premiums and λ
Source: Own elaboration

Figure 3 shows a hypothetical relationship between the tariff (p) and premium (σ) and the percentage of the upfront investment which is financed by a soft loan (φ), given λ^*. It has been built considering the usual data set, with λ^*=0.75. As expected, the values of p and σ decrease with reductions in φ.

[10] As before, the data set is referred to a photovoltaic plant, with I=3,500 €/kW; T=30 years; q=1,800 kWh/kW; i=0.06; ε=0.02; r^* =0.04; φ^*=0.5; τ=0.01, and e=0.05 €/kWh..

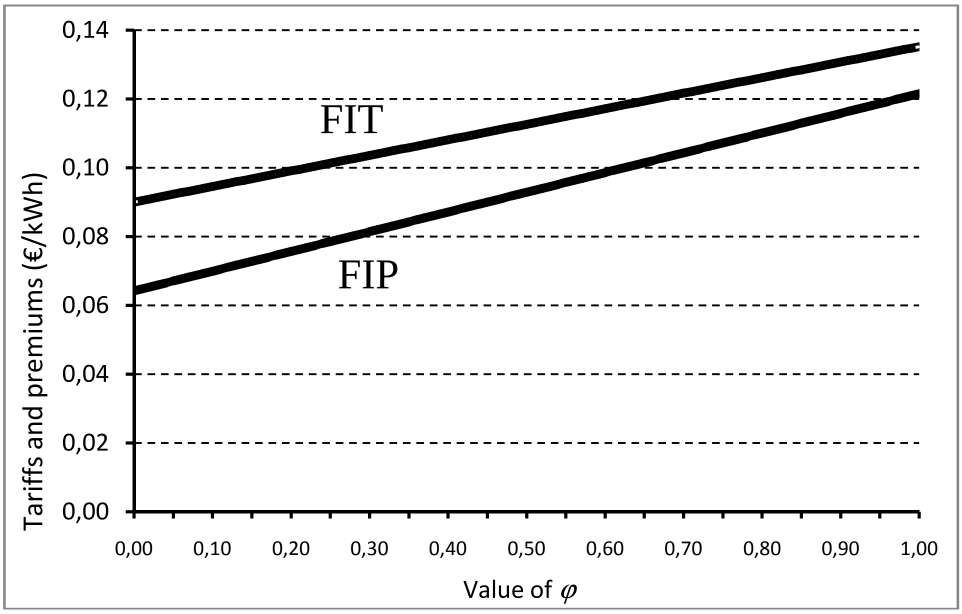

Figure 3. The relationship between premiums and soft loans.
Source: Own elaboration

In case of FIT the maximum value of the tariff is p_m=0.135 €/kWh and the minimum is p_n=0.09 €/kWh. In case of FIP, σ_m=0.122 €/kWh and σ_n=0.064 €/kWh.

As it was the case under the combination of FIP and subsidies, the required level of the premium in order to reach a certain level of profitability are also lower than the level under a tariff scheme. The increase in the pool price also leads to more favorable situations.

The general relationship between the three variables in case of FIT and FIP is shown in figure 4.

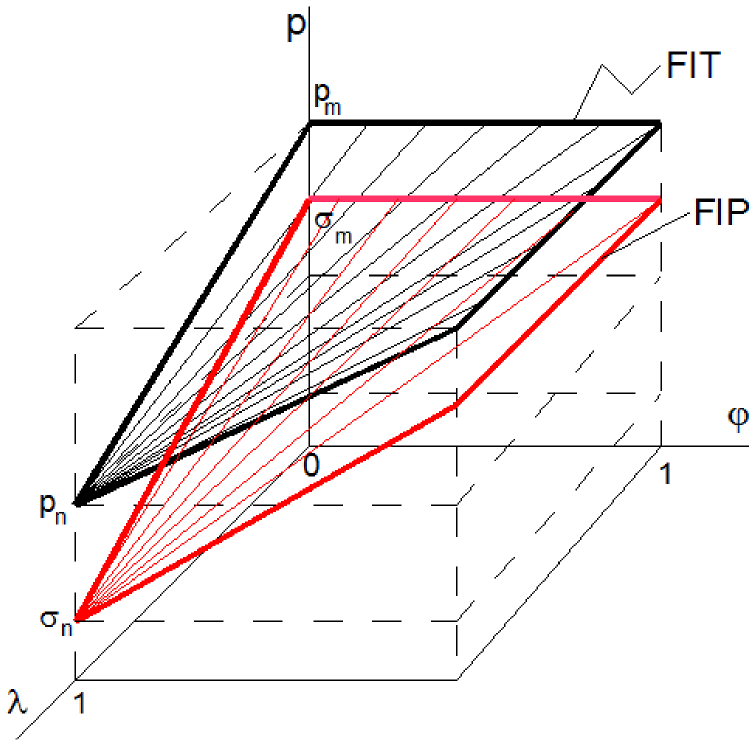

Figure 4. The p=f(λ, φ) and σ=f(λ, φ) surfaces
Source: Own elaboration

On the one hand, in the representation of the p=f(λ, φ) function, p_m and p_n refer respectively to the maximum and the minimum values of p. Analogously, in the case of the σ=f(λ, φ) function, σ_m and σ_n refer respectively to the maximum and the minimum values of σ. The distance between the p_m and σ_m points (both in position λ=0, φ=0) is smaller than p_n and σ_n (both in position λ=1, φ=0) because in expressions [14] and [18], $Z\cdot 1/T<1$.

On the other hand, if λ=0, then investors only have access to loans at commercial interest rates. Similarly, if φ=1, then there is no interest rate reduction. Of course, both situations overlap if $\lambda=\varphi=1$. In this case, p=f(λ, φ) and σ=f(λ, φ) are a constant functions whose value are respectively the maximum p and σ.

4. Changing the level of profitability and the discount rate

Coming back to equations [4] and [5], the relationship between p and r, and σ and r, can be expressed as follows,

$$p = \frac{I(\tau K + 1)}{qK} + \frac{I}{qK}r \qquad [19]$$

$$\sigma = \frac{I(\tau K + 1)}{qZ} + \frac{I}{qZ}r - e \qquad [20]$$

which are increasing straight lines. Tariffs and premiums move in the same direction as the net profitability index (r). From the above data set, the following (r, p) pairs are obtained: (0%, 0.1308), (10%, 0.1419), (20%, 0.1531) and (30%, 0.1642). With respect (r, σ) pairs we have (0%, 0.116), (10%, 0.13), (20%, 0.144) and (30%, 0.158). Thus, as shown by expressions [7]/[8] and [11]/[16], the p=f(γ), and σ=f(γ), functions and the surfaces p=f(λ, φ) and σ=f(λ, φ) will move in parallel up (down) to the increase (decrease) of r. For this reason, the higher the level of net profitability, the greater should be the proportion of the investment subsidy for a given level of tariffs or premiums.

The case of the discount rate is different because this term is included in the K and Z factors. From a financial point of view, the discount rate reveals the perceived risk of an investment project: its value and the alleged risk move in the same direction. Therefore, if i increases, K and Z decrease (towards an asymptotic value), since the denominator $(1+i)^t$ increases. Figure 5 shows the relationship between K and i for three levels of the inflation rate ($\varepsilon_3>\varepsilon_2>\varepsilon_1$). The higher the discount rate with respect to a given ε, the lower is K.

If the discount rate in the net present value expression is higher, investment subsidies partially lose their capability to reduce tariffs and premiums.

When FITs, or FIPs, and soft loans are combined, the additional effect induced by the following factors should be taken into account in order to assess the impact of the discount rate:

$$\lambda Z \frac{1}{T} + \lambda W i \varphi \qquad [21]$$

It is not difficult to prove that $Z \geq W$ because the values of the factor $\left(1 - \frac{t-1}{T}\right)$ range from 1 (when t=1) to $1/T$ ($t=T$), i.e., they are positive and below or equal to 1.

The terms Z and W are multiplied by different variables whose observed values are closer to 0. Therefore, the sum in [21] and the value of τ represent very small numbers. As a result, a higher discount rate has a greater impact on the denominator, in which there is K or Z, than on the numerator. The p=f(λ, φ) and σ=f(λ, φ) surfaces, i.e., the tariffs and premiums move up because of greater discount rate.

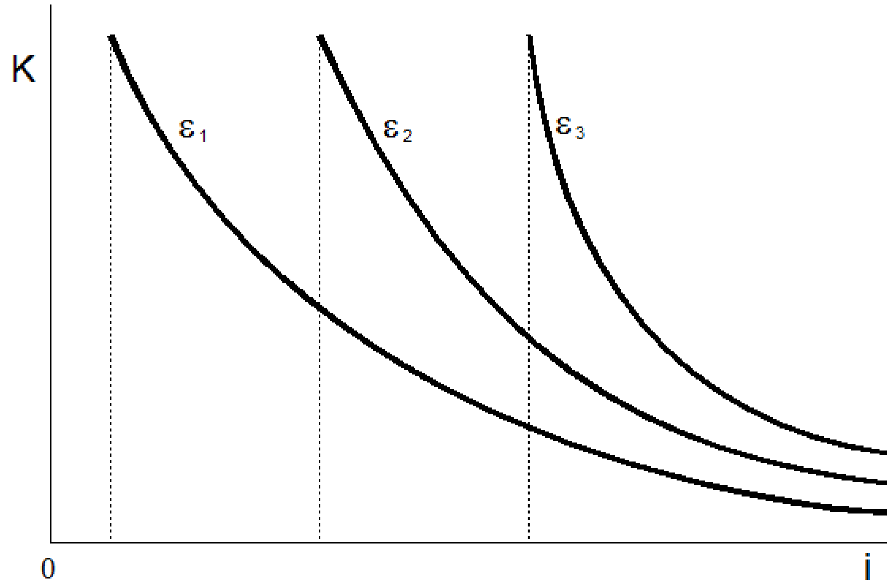

Figure 5. The relationship between K and the discount rate (i) for different levels of the inflation rate (ε).
Source: Own elaboration

5. The financial costs of instrument combinations.

Next, we compare the financial cost of combining FITs and FIPs and investment subsidies, or soft loans, with respect to a remuneration without such advantages. The analysis in this section is carried out for a representative RES-E plant, based on the models developed in section 3. These models only consider the stylised facts, so it should not be regarded as a comprehensive analysis of the global dynamics of such a policy**.** Obviously, an analysis of the total costs would require building up very complex models encompassing variables such as the time profile of new capacity entering into the generation mix, the tariff degression rate and the legal duration of support.

The overall cost of the support policy per installation (C_S) is defined as the net present value of the tariffs received during the lifetime of this installation plus the initial investment subsidy, i.e.,

$$C_S(\gamma) = p(\gamma)q\frac{1+\varepsilon}{i-\varepsilon}\left[1-\left(\frac{1+\varepsilon}{1+i}\right)^T\right] + \gamma I = p(\gamma)qK + \gamma I \qquad [22]$$

where γ is the proportion of the subsidised investment ($0<\gamma\leq1$) and $p(\gamma)$ represents its associated tariff. In case of FIPs the expression to be considered is,

$$C_S^{fip}(\gamma) = \sigma(\gamma)q\frac{(1+i)^T-1}{i(1+i)^T} + \gamma I = \sigma(\gamma)qZ + \gamma I \qquad [23]$$

Because both change according to the restriction $r=r^*$, the values of C_S and C^{fip}_S are constant. Furthermore, [22] and [23] have a $y=a+bx$ functional form. The starting point of these straight lines are the no investment subsidy case ($\gamma=0$). So, if both values are compared,

$$C_S(\gamma)-C_S(0)= p(\gamma)qK+\gamma I -p(0)qK=\gamma I, \quad 0<\gamma\leq1$$

and,

$$C^{fip}_S(\gamma)-C^{fip}_S(0)= \sigma(\gamma)qZ+\gamma I -\sigma(0)qZ=\gamma I, \quad 0<\gamma\leq1$$

With the aforementioned dataset, the value of $C_S(\gamma)$ is €4,251.027 and $C^{fip}_S(\gamma)$ is €3,012.192. Therefore, given the level of net profitability (r^*), the different combinations of tariffs, or premiums, and investment subsidies do not change the financial costs of the policy. However, there is a redistribution of the same amount of support between FITs, or FIPs, and investment subsidies. Subsidies could probably give rise to massive financial requirements at the beginning of such a policy, which is problematic at a time of high public budgets restrictions. Furthermore, the comparatively small amount of future tariffs does not mitigate this problem. But there is not an efficiency conflict between higher short-term costs and lower inter-temporal costs because the overall costs do not change: there is simply a different temporal distribution of financial resources.

Similarly to the case of investment subsidies, we analyse the cost of the combination of a FITs with soft loans for a representative installation. The expression of overall policy costs is,

$$C_S(\lambda,\varphi) = p(\lambda,\varphi)q\sum_{t=1}^{t=T}\frac{(1+\varepsilon)^t}{(1+i)^t} + (1-\varphi)\lambda iI\sum_{t=1}^{t=T}\frac{\left(1-\frac{t-1}{T}\right)}{(1+i)^t},\ \text{ with } 0<\lambda\leq 1 \text{ and } 0\leq\varphi<1$$

and with respect FIPs,

$$C_S^{fip}(\lambda,\varphi) = \sigma(\lambda,\varphi)q\sum_{t=1}^{t=T}\frac{1}{(1+i)^t} + (1-\varphi)\lambda iI\sum_{t=1}^{t=T}\frac{\left(1-\frac{t-1}{T}\right)}{(1+i)^t},\ \text{ with } 0<\lambda\leq 1 \text{ and } 0\leq\varphi<1$$

Both expressions represents the sum of the tariffs, or premiums, being paid plus the volume of interests being avoided by a representative plant over its lifetime. Obviously, these expressions change according to the values of λ and φ. These values modify the tariff and premiums provided that $r=r^*$. Analogously to the subsidies case, the strong connection between p, or σ, and λ an φ explains why C_S (λ, φ) and C^{fip}_S (λ, φ) are constant values (actually the same before indicated). The net present value of the amount paid to a plant which benefits from tariffs, or premiums, and soft loans does not change no matter the proportion of the investment being financed by preferential loans and the degree of reduction of the interest rate. There is also an internal redistribution of financial resources in the tariffs, or premiums, and soft loans combination.

6. Main conclusions.

In this paper, we have assessed the relationship between the support costs of combinations of deployment instruments for a given technology, compared to a situation when only one instrument (FITs or FIPs) is used. It has been found out that the policy costs of instrument combinations are the same as for the FITs or FIPs-only options, provided that the rate of net profitability and the discount rate do not change. The different levels of investment subsidies or soft-loans merely involve inter-temporal distributions of the same amount of policy costs. However, such inter-temporal distributions affect the social acceptability and political feasibility of renewable energy support. In particular, combining investment subsidies with FITs (or FIPs) involve greater policy costs in the short term compared with the FITs or FIPs-only option. This would be less socially acceptable and politically feasible. Combining FITs and FIPs with subsidies could be regarded by policy-makers as less attractive (and, thus, less politically feasible) than the FITs or FIPs-only option, which leads to a more uniform distribution of the costs of the policy over time.

Combining deployment measures is not a cost-containment strategy. Increasing the cost-effectiveness of support is an important topic at a time when governments, at least in Europe, are concerned about the increasing costs of RES-E support, mostly related (although not only) to solar PV support. This has been the case in Spain, Czech Republic, Italy, France or Germany, among others (Mitchell et al 2011, Müller et al 2011, European Commission, 2013).

Conversely, if the aim is to reduce this financial burden, the only way to do so is to induce lower values of the discount and the net profitability rates (assuming that basic technical and economical variables such as I, q and T, do not change). Public policy can contribute to reduce those policy costs by reducing the regulatory risks for investors, by adapting the level of support to technology costs and by controlling the increase in RES-E generation[11]. The former affects the discount rate, the two later influence the net profitability rate.

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