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A Panorama on Energy Taxes and Green Tax Reforms*

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Summary

This article provides an overview of specific and systemic applications of energy taxes and environmental (or green) tax reforms. To do so it combines a theoretical and empirical assessment of the literature, with a non-exhaustive description of the practice of these instruments and packages in the real world. Besides yielding a comprehensive approximation to the specific and systemic use of energy taxes, the paper contributes to the research in this area by reflecting on the present and future of these instruments in a particularly shifting world.

Keywords: Taxes, Energy, Environment, Externalities, Natural Resources.

JEL classification: H21, H23, Q48, Q58.

1. Introduction

Energy issues play an increasingly important role in contemporary developed and developing societies. This is due to the fact that the availability of reliable and sufficient energy is crucial for the development of economic activities and, therefore, the energy sector is nowadays very relevant and quite sizeable in most economies. But energy is also the source of important external (negative) environmental effects, particularly those related to the emissions of greenhouse gases (GHG) that are the cause of climate change phenomena. Moreover, the varying availability of energy resources across the globe brings about dependence relationships among countries that give prominence to energy security concerns.

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In this setting, the importance of public policies in the energy domain is obvious and growing. Energy policies are now topping the agendas of policymakers almost everywhere, and they are getting more complex due to the above-mentioned several objectives and trade-offs associated to energy production and consumption. Within energy public policies, the taxation of energy products has been applied with diverse intensity and scope (across countries and across energy goods) for several decades, although it is now rather generalized along the world and has seen remarkable increases since the 1980s. The reasons behind the wide and growing use of energy taxes are, first of all, purely fiscal: the size of energy consumption and its low reaction to price changes mean that this is a perfect candidate for taxation. Yet, environmental and energy security (in the form of a lower consumption of energy goods or a less-dependent energy supply structure) also explain many of the tax applications, especially in the last twenty years.

This article yields a general overview of the field of energy taxation that provides an interpretation on the reasons for energy taxes and on its practical applications. Yet the article does not attempt to be exhaustive, as the field is huge and many previous literature reviews have been already carried out quite successfully (see below). Our aim is to present a story on the development of energy taxes, showing both their theoretical foundations and some actual or hypothetical experiences. Moreover, we do not restrict the paper to the study of specific energy taxes as we feel that, increasingly, energy taxation is playing a wider role within tax systems and reforms. Finally, given the importance of these taxes and the changing fiscal, environmental and economic environments, this article is especially interested in a prospective analysis on the future of these fiscal instruments and packages.

As indicated above, the literature reviews on these matters have been abundant, with several recent examples. For instance, Newbery (2005) provides a good overview on the theoretical reasons behind energy taxes, and Lazzari (2005) studies different approaches to energy taxation. Metcalf and Weisbach (2009) focus instead on the different informational difficulties to determine optimal tax rates on energy. Also within an optimal tax approach, Bovenberg and Goulder (2002) or Fullerton *et al.* (2010) deal with environment-driven taxes, whereas Banfi and Filippini (2010) or Garnaut (2010) are interested in taxes levied on natural resources. Those are just a few illustrative examples within a very large and rich literature on specific applications of energy taxes, but their wider fiscal roles have also been quite explored after the seminal paper by Pearce (1991) on revenue-neutral carbon taxes. In this context, Ekins and Speck (2011) provide an updated overview of the theoretical conditions pointed out by the academic literature for the existence of a positive double dividend (environmental and economic) associated to an environmental tax reform. Besides, plenty of papers have been interested in the empirics of energy-related environmental tax reforms, as reported by the surveys of Bosquet (2000) or, more recently, Speck *et al.* (2011).

This article deals with specific and systemic applications of energy taxes, with theoretical and empirical approaches, and with a report on the practice of these instruments and packages in the real world. We feel that this comprehensive approach constitutes in itself a contribution to the literature, but perhaps the main novelty of the article is related to the reflection on the present and future of energy taxation in a particularly shifting world. The paper is thus structured in five sections, including this introduction. In Section 2 we present the theoretical reasons for the application of energy taxes: revenues, correction of environmental damage and capture of rents associated to an energy resource. The following section deals with the practice of energy taxes and environmental tax reforms, with an overview of the existing empirical literature and a selection of some applications in different countries. Section 4 focuses on the new environment for energy taxes and on the subsequent new proposals or alternatives both with specific and systemic approximations. The article concludes with a summary of the main findings and prospects regarding these matters, an extensive enumeration of references and an empirical appendix.

2. A theoretical context

There are several reasons that justify the existence of energy taxes, which can be roughly grouped in three main headings: revenue-raising motives, correction of environmental externalities, and capture of rents associated to natural resources that are used in energy production or consumption. In a recent paper, Labandeira (2011) suggested that each of these reasons had its ‘golden’ period: getting revenues for the public sector was behind the introduction of the first ambitious energy taxes in the developed world, back in the 1950s and 1960s, but are regaining momentum in this age of sizeable public deficits and weakening conventional taxes; environmental motives (particularly those related to climate change) were quite important in the 1990s and early years of this century; and the capture of rents associated to fossil fuels was first considered during the 1970s oil crises but has seen a recent surge together with energy efficiency and energy security concerns. The resulting vector has led to higher taxes on energy products in most developed and emerging countries, with obvious effects on energy systems, the economy and society [1].

In this section we present the theoretical foundations of energy taxes, largely from an efficiency point of view and in a rather superficial manner (e.g. without a proper general equilibrium framework). Our objective, as stated in the introduction, is confined to offering a wide vision of current and future developments in this area. In any case, it should be noted that the introduction of energy taxes may also bring about regressive effects on income distribution because, as energy products are generally necessary goods, the incidence of these taxes usually falls disproportionately on lower incomes (see Aigner, 2011). These distributional problems may justify the application of offsetting measures, which depend on the type of energy product (see Ekins and Dresner, 2004), with some practical illustrations later discussed in the paper.

2.1. Revenues

The nature of energy products makes them suitable candidates for revenue-raising purposes, as they may be the source of sizeable and stable public receipts. Indeed, energy goods generally show a low (inelastic) elasticity of demand (see table 1), so tax-induced price variation has limited effects on consumption and thus on the amount and stability of revenues. Moreover, the relationship between energy demand and income is not monotonic, with a trend for energy intensity to grow (decrease) with output in low-income (high-income) economies (see e.g. Galli, 1998 and Wu, 2012). The main reasons that explain this phenomenon are changes in the structure of final demand, increases in end-use energy efficiency, and substitution of less efficient fuels (Bernardini and Galli, 1993). The preceding means that taxes on energy are an increasing revenue source for emerging and developing countries, as long as they are in a growing economic path, although development may actually limit the growth of such revenues (see also footnote 1).

Table 1
ENERGY PRICE-ELASTICITIES IN THE ACADEMIC LITERATURE

Authors	Country	Energy product	Price-elasticity
Bentzen and Engsted (1993)	Denmark	Energy	[–0.47, –0.14]
Rothman *et al*. (1994)	53 countries	Energy	[–0.78, –0.69]
Koopmans and te Velde (2001)	Netherlands	Energy	–0.29
Hunt *et al*. (2003)	United Kingdom	Energy	–0.18
De Vita *et al*. (2006)	Namibia	Energy	–0.34
Filippini and Hunt (2011)	29 OECD countries	Energy	[–0.4, –0.2]
Holtedahl and Joutz (2004)	Taiwan	Electricity	–0.16
Kamerschen and Porter (2004)	USA	Electricity	–0.93
Narayan and Smyth (2005)	Australia	Electricity	–0.26
Labandeira *et al*. (2012)	Spain	Electricity	–0.25
Baker *et al*. (1989)	United Kingdom	Natural Gas	–0.31
Baker and Blundell (1991)	United Kingdom	Natural Gas	[–0.62, –0.41]
Maddala *et al*. (1997)	USA	Natural Gas	–0.01
Vásquez *et al*. (2011)	USA	Natural Gas	[–0.41, –0.11]
Baltagi *et al*. (2003)	France	Gasoline	–0.01
Pock (2010)	14 European countries	Gasoline	–0.09
González-Marrero *et al*. (2012)	Spain	Gasoline	–0.29
Lin and Zeng (2013)	China	Gasoline	[–0.497, –0.196]

Source: The authors from the literature above.

The theoretical, efficiency-related, basis for energy taxes is to be found in the theory of optimal taxation. This theory assumes that the introduction of any tax (except lump-sum alternatives) affects the behavior of individuals and thus reduces welfare. On the one hand, the tax payment involves the transfer of resources between the private and public sectors, reducing disposable income of agents and thus creating an income effect. Moreover, taxes alter relative prices and introduce a substitution effect (favoring the consumption of the goods that are less affected by taxation) that produces a second welfare loss. The objective of optimal taxation is to minimize welfare losses through a second-best (i.e. sub-optimal) tax structure.

Optimal commodity taxation is based on the seminal work of Ramsey (1927), whose partial equilibrium model will be next employed to justify the use of energy taxes following a Sandmo (1976) simplification.

Let us thus assume a closed economy, with perfect competition, where *n+1* goods and services (including labor) exist. The public sector levies an *ad-valorem* tax, t_i^r, on the consumption of each good *i* to obtain revenues which cover public expenditures (*T*) that are assumed to be exogenous and fixed. The public sector seeks the minimization of the welfare losses of the preceding taxes, with the following optimization program,

$$\begin{aligned} &\underset{\{t_1,\ldots,t_n\}}{Max}\ u(x_0, x_1, \ldots, x_n) \\ &s.t \sum_{i=1}^{n} p_i t_i^r x_i = T \end{aligned} \qquad (1)$$

where *u* is the utility function of a representative consumer, p_i the producer price and x_i the consumed quantity of each good.

Consumers, on the other hand, look for a combination of consumption of goods that maximizes its individual utility, subject to their budget restriction (with x_0 as time devoted to work and *w* unit salary),

$$\begin{aligned} &\underset{\{x_0,\ldots,x_n\}}{Max}\ u(x_0, x_1, \ldots, x_n) \\ &s.t \sum_{i=1}^{n} p_i (1+t_i^r) x_i = w x_0 \end{aligned} \qquad (2)$$

From the first-order conditions of the previous problems, assuming that demand functions have null cross price elasticities [2] and with some further simplifications, we obtain the optimal tax rates,

$$t_k^r = \frac{\alpha+\lambda}{\lambda e_{kk} - (\alpha+\lambda)} \quad \text{k=1,...,n} \qquad (3)$$

where e_{kk} is the price elasticity of good *k* and *α* and *λ* are the Lagrange multipliers of the previous optimizations. This result indicates that goods with a lower price elasticity of demand should be more heavily taxed. As the empirical evidence shows that price elasticities of energy demand are quite low, this justifies the widespread use of these taxes in the real world.

Yet energy products, as well as being consumed by households, may be employed as inputs in the different production processes. In this context, the theory of optimal taxation is contrary to the use of taxes on intermediate goods to avoid productive inefficiencies because, in absence of profits, the introduction of such taxes would also bring about changes in final prices but with further inefficiencies in the production area (Diamond and Mirrlees, 1971). This result explains the generalized use of neutral consumption taxes, such as ideal VAT (i.e. far from many actual applications), in most of the developed world and of lower intermediate consumption taxes on some energy goods (e.g. diesel for transportation, compared to gasoline) to benefit commercial or productive activities.

2.2. Environmental correction

A second important reason for using energy taxes is the control of the environmental externalities that are widely present in energy production and consumption: from the emission of local or global pollutants to water usage or, among many others, to the risks associated to the management of nuclear waste. This is the classical example of market failure and public intervention to solve it, as first stated by Pigou (1920).

To illustrate the theoretical foundation of energy-related environmental taxes, we now employ a model with a representative consumer and a single firm that produces a good x_1 using an energy input z and discharging pollution to the atmosphere (e) that causes environmental deterioration [$b(e)$]. In this context, if social welfare is maximized,

$$\begin{aligned} &\underset{\{x_1,b\}}{Max}\, u(x_1,b) \\ &s.t \\ &x_1 = x_1(z,e) \\ &b = b(e) \end{aligned} \tag{4}$$

F.O.C

$$\frac{\partial x_1}{\partial e} = -\frac{\dfrac{\partial u}{\partial b}\dfrac{db}{de}}{\dfrac{\partial u}{\partial x_1}} \tag{5}$$

That is, the optimum requires that marginal private benefits (or marginal abatement costs) and marginal external costs are equal. However, in a free market situation without environmental regulations the firm would seek maximum profits,

$$\underset{\{e,z\}}{Max}\, x_1(z,e) - p_z z \tag{6}$$

where p_1, the price of good x_1, is normalized to 1.

F.O.C

$$\frac{\partial x_1}{\partial e} = 0 \tag{7}$$

This means that the firm would produce until its marginal private benefits are zero, without achieving the optimum. To solve this problem, a corrective or Pigouvian tax could be introduced with a tax rate, t^e, that would be equal to the marginal external costs of emissions in the optimum [3],

$$t^{e} = \frac{\frac{\partial u}{\partial b}\frac{db}{de}}{\frac{\partial u}{\partial x_1}} \tag{8}$$

However, implementing the preceding tax in the real world is problematic due to the large informational requirements. Indeed, to determine the Pigouvian tax rate, it would be necessary to know the optimal levels of marginal external costs (*MEC*) and private marginal benefits (*MPB*), thus requiring the estimation of both curves in a long interval [4]. But obtaining reliable information on the preceding curves is not straightforward: estimating marginal external cost functions is costly and usually a very complex endeavor [5], whereas the calculation of private marginal benefits (or marginal abatement costs) is subject to problems of asymmetric information [6].

The previous problem can be overcome through the so-called second-best approach to environmental taxes: by using taxes, the regulator knows that all polluters will reveal their marginal abatement cost because they would prefer abatement to paying taxes as long as the former is a less costly option. This would lead to minimization of total abatement costs for achieving a certain (exogenously pre-determined) environmental objective without the need of calculating the external and abatement cost curves (i.e. with implicit revelation of those curves), although the result would be obviously sub-optimal (see e.g. Fullerton, 2001 and Stavins, 2003). An example of such approach in climate policy would be using carbon taxes to attain the 2ºC objective.

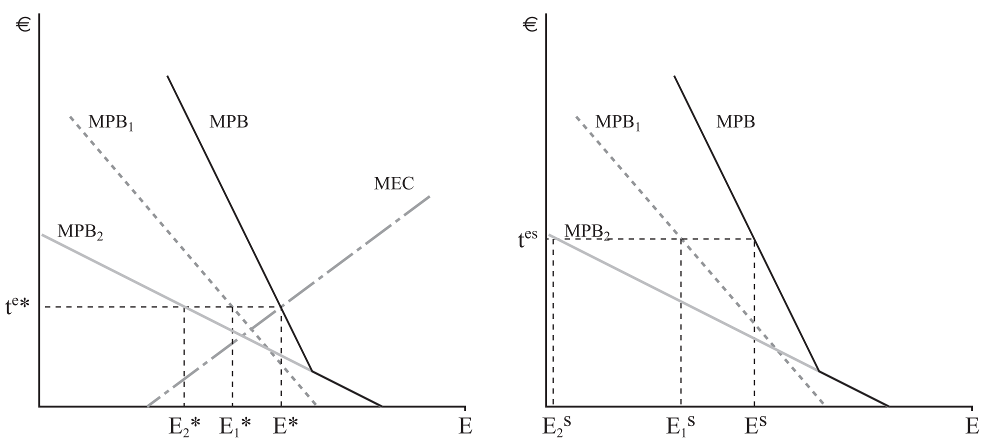

Figure 1. Pigouvian (left) and cost-effective (right) approaches to environmental taxation
Source: The authors.

Figure 1 depicts the first-best Pigouvian tax rate, derived from a cost-benefit optimal analysis of pollution, and the second-best sub-optimal option when two emitters (1 and 2) are present. In the illustration the sub-optimal level of pollution (E^s) is below the Pigouvian optimal outcome (E^*), and thus the suboptimal environmental tax rate (t^{es}) is larger than the Pigouvian tax (t^{e*}), but the opposite may also occur. Note that in both cases the level of emissions is achieved at a minimum total abatement cost.

2.3. Capture of economic rents

Energy products are either natural resources themselves or their production involves the use of renewable or non-renewable natural resources such as wind or petroleum. This is relevant to this paper because natural resources are usually associated to the existence of the so-called economic rents: the present value of the economic benefits that are related to their exploitation (as a difference between discounted real income and costs; see Boadway and Flatters, 1993). Policymakers may be interested in this issue because natural resource rents can be 'extraordinary', i.e. well above the usual retribution of the productive factors that are needed to carry out an economic activity. This explains several recent tax applications on non-renewable or renewable energy-related natural resources, notably the Australian tax on some mining activities. However, most academic and policy discussions on this matter have referred to the distribution among producing and consuming countries of the economic rents associated to non-renewable natural resources of energy nature (particularly, oil).

Indeed, a casual observation of the strategies by oil exporting and importing countries provides some interesting insights. On the one hand, most exporting countries operate within cartel structures that manipulate supply to achieve certain price levels that obviously influence the size of economic rents. On the other hand, many consuming countries use taxes on energy consumption to try to capture part of the economic rent associated to the energy-related resource. To illustrate rent capturing by importing countries we next use the simple single-period Bergstrom (1982) model.

Let us assume that there are *m* countries that exploit an energy natural resource, with irrelevant extraction costs, and *n* countries that import the energy resource. We further assume that producers devote all the resource to exports and have a perfectly inelastic supply (perhaps because they are fully exploiting the resource and changing the level of production would be quite costly). In this sense, S is the total supply of the energy resource in the international markets, $S=\sum_{j=1}^{m} S_j$, with S_j as the supply by country j and $\hat{p}$ the international (i.e. valid for all countries due to arbitration possibilities) price of the resource.

Let us suppose, in this context, that the importers jointly agree to set an *ad valorem* tax on the consumption of the energy resource, t^c. Consumers will pay in this case,

$$p=\hat{p}(1+t^c) \tag{9}$$

Given that demand is in each country a decreasing function of price, there will be an aggregate reduction of demand and thus an excess supply. As producers have an inelastic supply, exporters will reduce prices so that importers pay the same gross of tax price as before, i.e. the new price received by exporters, $\hat{p}$', will be

$$\hat{p}' = \frac{\hat{p}}{1+t^c} \tag{10}$$

This means that, after introducing the above-mentioned tax, the importing countries are able to capture a share of the rent associated to the energy-related natural resource,

$$\hat{p}\frac{t}{1+t^c}Q^* \tag{11}$$

with Q^* as the total consumed quantity of the energy resource. This is also illustrated by figure 2, where *D* is the aggregate demand function, *D'* the aggregate demand function seen by producers after the introduction of the tax, and *Q'* the demand when the tax is introduced (before the price adjustment by producers). The shadowed area depicts the part of the economic rents captured by the consuming countries.

To conclude, and under the preceding restrictive conditions that may only hold in the short term, when energy producers use a cartel to maximize the economic rents associated to a natural resource, consuming countries could employ energy taxes to capture a big share of the rent (in direct proportion to the size of the tax). And this would be achieved without internal (i.e. in the consuming countries) efficiency costs, as the price paid by consumers would be independent of the tax rate. Moreover, in terms of energy security such a tax could be employed by the importers as a tool to tackle price volatility and would also reduce energy consumption and thus have positive effects on security through less external dependence (see e.g. Labandeira and Manzano, 2012).

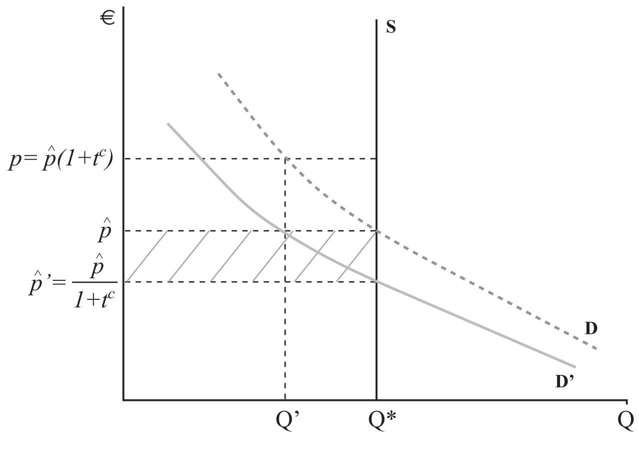

Figure 2. Capture of rents associated to an energy resource through taxation

Source: The authors.

2.4. General theoretical messages

The preceding sub-sections have dealt with the three main reasons, in an independent fashion, for using energy taxes. Since each of those reasons supports the introduction of energy taxes, a combined consideration of them would reinforce the case for energy taxation, at least intuitively. Summing up, it seems that the best option would be to tax the final consumption of inelastic energy goods whose use generates environmental problems and whose supply is controlled by a limited number of foreign agents. Moreover, trade-offs between the different reasons may exist, which introduce doubts on the previous simplistic message: by increasing the energy tax due to environmental reasons, for instance, would affect the revenue-raising capacities (perhaps reducing them substantially in the longer term). Therefore, the design of an energy tax that simultaneously deals with all those matters is not straightforward, as we will observe in the following section. For instance, this would clearly apply to one of the most important sources of energy tax revenues in most countries, oil excises (see Section 3.3.1), as they also play environmental and rent-capture roles whose effectiveness may be affected by their revenue objectives.

Actually, the theoretical literature on environmental taxation has been quite aware of the multiple objectives pursued by a single tax instrument, a phenomenon that brings about several analytical and instrument-design difficulties. Sandmo (1975), Bovenberg and van der Ploeg (1994) and Cremer *et al*. (1998), among others, incorporated environmental externalities into the optimal tax problem concluding that in this case there were reasons for increasing the size of the consumption tax: the final tax level should indeed be an average (weighted by the marginal cost of public funds) of the good's inverse price elasticity and the social benefits of reducing pollution associated to the good (Sandmo, 2011). Moreover, the use of energy taxes with simultaneous rent-capture and environmental purposes has been analyzed by a number of papers (see, e.g., Bergstrom, 1982; Liski and Tahvonen, 2004; or Dong and Whalley, 2012).

Yet the relationship between some of the preceding reasons for energy taxes is probably best exemplified by the so-called theory of double dividend. Although Tullock (1967) first mentioned the 'extra' fiscal benefits of environmental taxes many decades ago, the theoretical enquiries on this matter boomed in the 1990s when the potentially sizable and stable public revenues associated to carbon, i.e. energy-related, taxes made them suitable to lead tax reform processes (Pearce, 1991). In this case the debate is slightly different to the presented in Section 2.1: now the environmental benefit brought about by the energy tax is taken for granted and public revenues (T) are fully devoted to efficiency-enhancing reduction of other (distortionary) taxes, thus creating a kind of double benefit (Goulder, 1995). This means that the revenue-raising side of the energy-related environmental tax would play a substantial and additional role with obvious effects on other non-revenue-oriented objectives and tax rates.

The large and intense research effort on the existence and size of the dividends associated to environmental taxes is behind the so-called green tax reforms, which are considered in the following section. In this sense, the underlying theoretical assumptions and results on multiple benefits from environmental taxes have been widely discussed and analyzed (see e.g. Bovenberg, 1999; Katrena, 2002), although the mainstream view now acknowledges the existence of a tax interaction effect that generally precludes the achievement of a strong double dividend (simultaneous positive environmental and fiscal dividends from the package) but still recommends full revenue recycling to maximize welfare (weak double dividend). Indeed, the literature has clarified the importance of external factors for the sign and extent of the second (non-environmental) dividend: Schöb (1996) stressing the relevance of the pre-existing fiscal structure, Bovenberg and de Moiij (1997) highlighting the role of capital mobility when taxes on capital are considered for revenue-compensation, and Heady *et al.* (2000) underlying the significance of institutional frameworks for wage-setting when using tax receipts to reduce labor costs.

In sum, there is substantial theoretical support for the use of energy taxes from different perspectives. It seems, however, that revenue-raising motives are playing an increasing role due to external demands for expanded public receipts in many countries in recent years and to the fact that energy-related taxes may be used as a core of tax reform processes (e.g. green tax reforms). This requires a detailed and comprehensive approach to the issue, which is unfortunately lacking in most of the academic literature so far, especially in the fields of energy dependence and rent capture. In particular, we deem especially necessary to carry out a deep analysis and reconciliation of the synergies and negative interactions between tax rates that primarily seek environmental correction (t^e), reduction of fossil fuel imports (t^c) and public receipts (t^r). Indeed, given that energy taxes may have as a primary aim to reduce environmental damages through changes in technologies and/or behavior of polluters, energy tax bases and thus revenues may therefore be affected in the medium and long terms. Hence the search for higher revenues may have negative effects on capture of rents associated to energy resources or on environmental protection (e.g. through the use of lower-than optimal or sub-optimal energy tax rates) and vice versa (e.g. energy efficiency improvements [7], with environmental or energy security purposes, would reduce the energy tax base).

With all the preceding in mind, this section has attempted to provide the rudiments of such an overall approach, as further developments are beyond the objectives and capacities of this article. This will be complemented by the conclusions of the subsequent parts: given that the fundamentals of energy taxation have obvious effects on tax design, including the selection and structure of tax bases and tax rates, we next deal with that issue.

3. The practice of energy taxation

3.1. Energy tax design

When dealing with energy tax design in practice, a first enquiry should refer to the possibilities and constraints of transferring the previous theoretical insights and recommendations to reality. This is not an easy task, first of all because of the above-mentioned tax interactions between objectives. Second, because energy taxation is a rather generic theoretical term that in practice includes a wide array of applications and technical solutions. For instance, energy taxes could be levied on the appliances that consume energy, on the act of energy consumption or on both. Moreover, energy taxes could be calculated on the amount of consumed energy (e.g. Liters of fuel), or on the calorific content of the energy products (e.g. Terajoules), or on the emissions associated to consumption. Energy taxes could also use *ad valorem* or unit tax rates, etc. We next discuss some of these issues, mostly with a normative approach, before surveying the empirical literature on the effects from energy taxes and presenting some examples of real-world applications of these instruments and fiscal packages in different areas.

When consumption taxes seek different objectives, as is the case with energy goods, this strongly influences technical design. In this sense, Sandmo (1976) showed that revenue-raising tax rates should be applied over and above the corrective tax rates. This result led Gupta and Mahler (1994) or Crawford and Smith (1995), among others, to suggest the use of unit taxes (i.e. levied on the physical levels of consumption) to control environmental externalities, and to employ *ad-valorem* taxes (i.e. levied on the preexisting price levels) over and above unit taxation to attain public revenues. This probably explains the actual applications of fuel taxes in many developed countries (such as the EU), where unit taxes on physical consumption are exacerbated by a subsequent application of the general sales tax. However, given the strong price fluctuations of many energy goods, revenue stability may be better achieved through unit taxation and thus introduces an exception to the general rule. Yet another reason for using *ad-valorem* taxes with revenue-raising purposes is the availability of neutral value-added approaches that would minimize inefficiencies on the productive sector (see Section 2.1).

Energy taxes could be, on the other hand, defined in upstream or downstream fashions. By using the more common upstream approaches, the (unit or *ad-valorem*) energy tax is levied at some upper point and then transmitted through the economy. This obviously reduces administration and compliance costs, but may prevent a proper attainment of some of the previously mentioned objectives of energy taxes. For instance, downstream energy taxes may improve the behavioral reaction by agents to environmental tax signals (Hanemann, 2009) and thus be more effective.

Administration and compliance costs may be also behind the use of purchase (and redundant) taxes on durables that are associated to energy consumption. In most countries that is best exemplified by automobile taxation, or by specific taxes on household appliances and new proposals on housing taxes (see Sections 3.3 and 4.2). In this sense and under certain conditions, Fullerton and West (2002) showed that a combination of car and fuel taxes might resemble a pure tax on emissions. Given that many (mainly local) energy-related pollutants are not easily measurable, such a combination could help achieving the environmental objectives of energy taxes. However, a large focus in taxes on durables may affect revenue, corrective and rent-capture objectives as such instruments usually show a low linkage between the tax base and energy consumption (e.g. it is not clear that actual energy consumption will be well targeted by taxing car size).

Another problem related to (such) an imperfect taxation of energy consumption is cost-effectiveness. In figure 1 we showed how environmental taxes (or other pricing regulatory instruments) minimize total abatement costs associated to any emissions level. When minimization of total energy use is the objective, in order to reduce energy dependence and improve energy efficiency, a similar result would hold. In this context, this means that if environmental reasons are not considered, energy taxes should be extensive, i.e. should be applied across all energy goods and with equal tax rates across the board. Figure 3 depicts current tax levels, in implicit carbon and energy content taxes (respectively dark and light gray) for a number of energy goods in Spain, although a similar situation is observed in most developed countries. It is clear that the diversity of tax treatments across energy goods reflects a largely inefficient outcome that could be explained by administrative, political or distributional constraints.

Indeed, distributional issues are an important factor for the definition of energy taxes and tax packages. Since most energy services are often seen as necessities, as observed in Section 2, taxing energy goods would be regressive. However, by excluding or benefiting goods with a more regressive outlook, energy taxes could mitigate distributional problems (which could be behind the erratic situation shown by figure 3). Moreover, energy tax revenues could be also employed to offset negative distributional effects (see, e.g., Vandyck and Regemorter, 2014), although using receipts with that purpose would contradict the mainstream revenue-recycling (double dividend) efficiency view (see Sahlén and Stage, 2012).

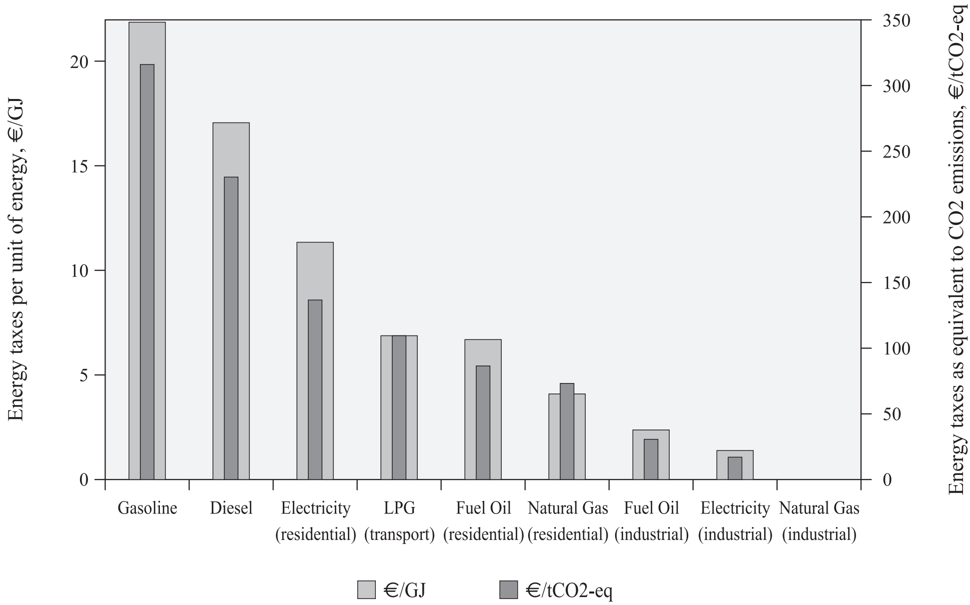

Figure 3. Implicit taxes on carbon emissions and energy contents. Spain

Source: The authors with information from IEA (2013)

Notes: All data are from 2013, except natural gas (2012) and electricity (2011); the conversion factors from GJ to CO_2-eq were obtained from European Commission (2007) and OCCC (2013).

In practice there are many other examples of earmarking energy tax receipts: environmental protection, promotion of renewables, increases in energy efficiency, etc. Yet, as stated by Heine *et al*. (2012), earmarking should be ideally restricted to cases in which spending brings about efficiency benefits similar to those from revenue-recycling. With a different approach, Loureiro *et al*. (2013) have shown that revenue-earmarking may facilitate the introduction of energy tax packages given the existing public preferences on these instruments.

3.2. Some empirics of energy taxation

Many research papers have explored the economic and environmental effects from the introduction or increase of energy taxation, either individually or as part of wider tax reform schemes. These papers have usually employed *ex-ante* simulations based on purely hypothetical taxes and tax reform packages or on policy proposals by governments or supranational entities such as the EU. *Ex-post* empirical analysis on real energy tax experiences are less common, due to limited tax applications or to lacking data, but have been occasionally carried out. Bosquet (2000), Barker *et al.* (2011), Speck and Gee (2011) or Ekins and Speck (2011) are useful overviews of the empirical methodologies and results from this rich literature. These issues have been also considered in several Spanish surveys and policy papers (see e.g. Gago *et al.,* 2004 or Labandeira *et al.,* 2009).

In this section we report the results from a review of 699 simulations, using different models and methodologies, from 100 papers on the effects of different taxes that have in common that are applied to one or more energy products, in most cases with an environmental rationale and part of wider tax reform schemes (see footnote 5). These papers are specifically reported in a separate section of the references of the article, with figures 4 and 5 summarizing the main effects of energy taxes, presenting the percentage changes in key variables from a business as usual situation.

Figure 4 shows the effects of energy taxes on prices and demand of energy goods. In this sense, the price impact of energy taxes is significant (over 20%) in approximately 40% of the empirical applications, although it does not lead to similar reductions of energy demand. This confirms the above-mentioned low price elasticity of demand of these goods (one of the reasons for taxing energy: see Section 2.1), as stressed by Beaumais and Bréchet (1995) or Siriwardana *et al*. (2011). The empirical literature also indicates that when taxes are only levied on particular energy goods, there might be a significant substitution by untaxed goods: over 20% of cases there is an increase in the demand of other energy goods. Yet the overall price-related demand variations are usually of little significance: about 70% of the empirical papers show changes in the ±5% range.

The environmental effects of energy taxes have been also addressed by most of the empirical assessments, as environmental protection was identified as a major reason for the use of these instruments. Many papers have focused on greenhouse gas emissions (particularly carbon dioxide), given the potentially large negative effects of climate change, although carbon dioxide emissions can be also used as a proxy of other fossil fuel related emissions that generate local or regional environmental problems. Figure 4 also summarizes the effects on carbon dioxide emissions (CO_2) in the surveyed literature, showing that in general energy taxes are effective in the reduction of carbon dioxide emissions, with 95% of the simulations reporting decreases in emissions with respect to the business as usual scenario.

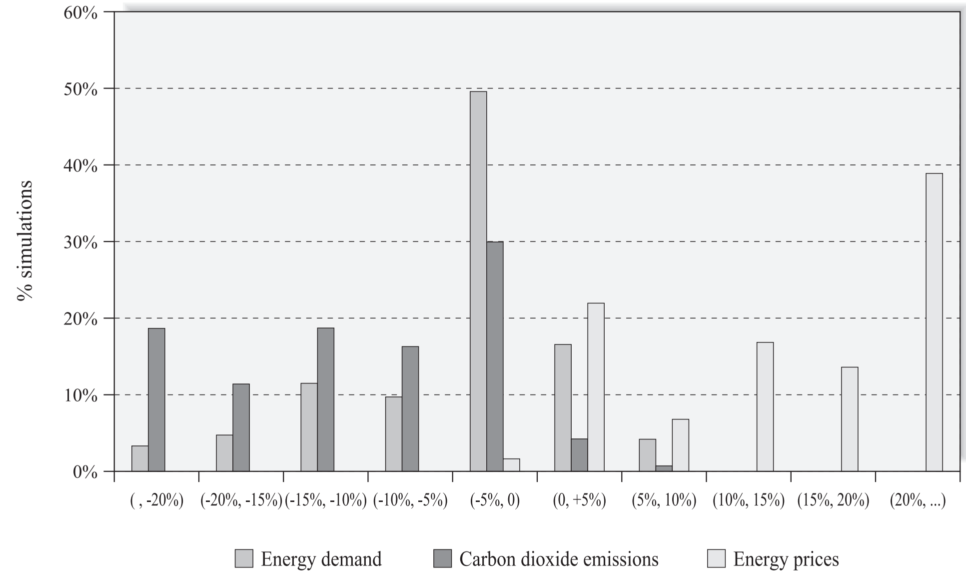

Figure 4. Effects of energy taxes on energy demand, energy prices and CO_2 emissions
Source: The authors from the empirical literature.

New or increased energy taxes may cause macroeconomic effects, as illustrated by figure 5. As depicted in the figure, impacts on GDP, welfare, employment or on the consumer price index (CPI) are usually of little importance, again usually in the ±5% range. Results are more favorable when energy taxes are part of tax reform schemes (Barker *et al*., 1993; Welsch, 1996; Labandeira *et al*., 2004), and particularly good in terms of employment if energy-tax receipts are employed to reduce social security contributions (Barker, 1998; Conrad and Smith, 1998; Bach *et al*., 2002).

Regarding distributional effects, most empirical exercises (77%) report negative impacts, which is also confirmed by recent surveys (EEA, 2011; Ekins and Speck, 2011). However, such regressivity should be interpreted with care because there might be sizable differences within income groups, and impacts are likely to be very different when considering the type of energy consumption too. With respect to the former, Dresner and Ekins (2006) indicate that differences within the same income group may be even bigger than across income groups, as is the case with similarly affluent rural and urban households who are likely to face rather different energy tax burdens due to varying transport or heating needs. Regarding the latter, Ekins and Speck (2011) or Kosonen (2012) point out that energy-related transport taxes are usually less regressive than those levied on gas, coal or other heating fuels: indeed transport taxes could be progressive at times, as observed in some emerging and (under certain conditions) developed economies such as the U.S (Rausch *et al*., 2010), Poland (Kiuila and Sieszynkski, 2003), Spain (Labandeira and Labeaga, 1999) or Serbia (Sterner, 2012a).

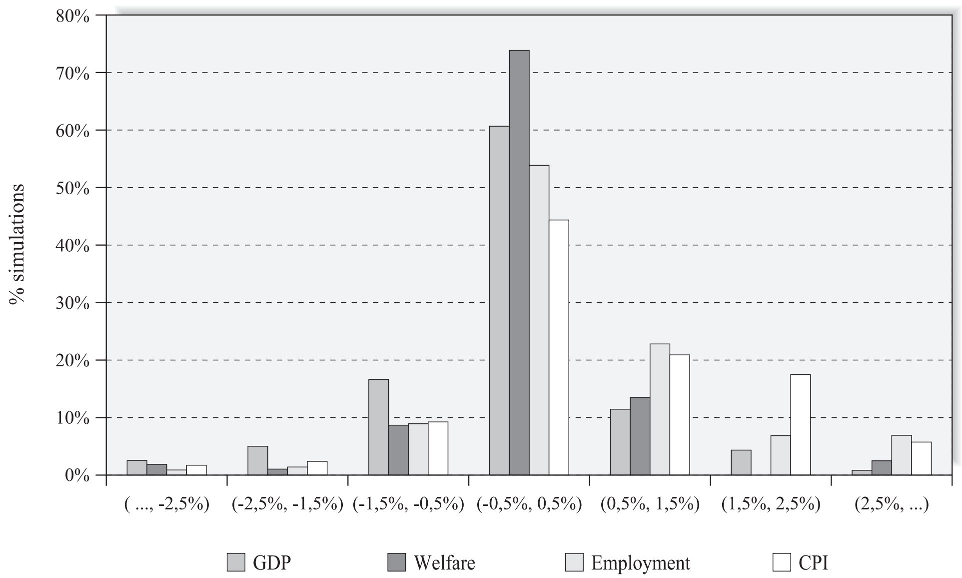

Figure 5. Main macroeconomic effects from energy taxes

Source: The authors from the empirical literature.

Since we have a very heterogeneous set of simulations that also use different models and methods, there is considerable variation in the effects of energy taxes on the considered variables. Thus, basic meta-regression analysis is used to synthesize the effect on each variable in a single value, following the procedure suggested by Nelson and Kennedy (2009), through the methodology proposed by Stanley and Jarrell (1989),

$$b_j = \beta + \sum_{k=1}^{K} \alpha_k Z_{jk} + e_j \qquad (j = 1, 2, ..., L) \tag{12}$$

where b_j is the reported estimate of the 'true' value of the effect (β) in the j^{th} study, Z are the independent variables that measure relevant characteristics of the empirical study that influence the estimated effects, α_k are the meta-regression coefficients which reflect the biasing effect of particular study characteristics, e_j is the disturbance term, and L is the number of studies used.

The papers used for the meta-analysis were selected from a detailed and wide review of the existing literature on energy taxation. Although most papers have been published in peer-review journals, we have also included several working papers due to their relevance and interest. Most papers used to produce figures 4 and 5 were also used for the meta-analysis: only 3 papers (over 100) were not considered due to lack of information on crucial variables, although a number of specific simulations were not included in the analysis due to missing details on the size of the tax [8].

Given the heterogeneity of empirical studies, which leads to a remarkable variation of the effects from energy taxes, we introduce several dummies to gather the different sources of heterogeneity. First, we use dummies indicating the type of model used to simulate the impacts of energy taxes [9]. Dynamic general equilibrium models were used as benchmark because they are the most common models in the existing literature on these matters. We also include other dummies that indicate the size of the tax reform (implemented *ad valorem* tax rate), country characteristics, government level, tax characteristics, and whether the simulation considers revenue recycling through a green tax reform and what kind of reform (see table A.1. in the Annex).

To avoid heteroscedasticity and correlation problems we estimated the model for each of the effects considered by generalized least squares, obtaining the results depicted in table 2 [10]. We see again that on average the effect of energy taxes on energy prices is relevant, although this increase does not result in important effects on energy demand and macroeconomic variables. Moreover, the average CO_2 emissions reduction in the considered studies is slightly above 14%. In fact, only the average effects on energy demand, energy prices and CO_2 emissions are statistically significant. In general, the tax rate, the energy import/export status of the country, and using tax revenues to reduce social security contributions are the variables with a bigger influence on results. In particular, the introduction of a green tax reform that recycles tax revenues through a reduction of social security contributions has a statistically significant positive effect on GDP, employment and welfare and a negative effect on the CPI.

Table 2
AVERAGE EFFECTS FROM ENERGY TAXES IN THE EMPIRICAL LITERATURE

	$\hat{\beta}$
Energy demand (END)	–3.79%**
Energy prices (EP)	29.34%*
GDP	–0.16%
Employment (EMP)	–0.37%
Welfare (WEL)	–0.04%
CPI	–0.79%
CO_2 emissions	–14.82%***

Note: We indicate significance by *** at the 1% level, ** at the 5% level, and * at the 10% level.
Source: The authors.

In sum, after the wide empirical research program carried out in the last few years, the effects and incidence of energy taxes seem now quite clear. In general, energy taxes lead to increased prices that hardly affect energy demand, with limited macroeconomic effects whose sign is especially improved when preexisting labor taxes are lowered through energy tax receipts. Indeed, green tax reforms can obtain significant emission reductions at limited economic cost and with scarce effects on competitiveness (OECD, 2004; Agnolucci, 2011; Speck *et al*., 2011). Moreover, most studies confirm the usual regressivity of energy taxation, although a more diverse distributional picture (with occasional proportional or progressive effects of energy taxes) has been emerging in the last few years.

3.3. Energy taxes and related tax reform schemes in reality

3.3.1. *Energy taxes*

In this sub-section we first deal with the revenue relevance of energy taxation, followed by a discussion on the actual implementation of energy taxes in practice. The description intends to cover the most relevant realities in today's world: developed, emerging and oil-producing countries.

Energy taxes were already mentioned as a major source of public revenues, especially in advanced countries. For instance, in 2011 these taxes represented 4.6% of total receipts (1.8% of GDP) in the European Union even without considering the VAT revenues from energy products (European Commission, 2013). Figure 6 reports the relative size of energy taxes as a percentage of GDP across EU countries in 2011, which depicts quite a large variation between member states [11]. Other developed countries such Australia or Japan show similar figures (respectively 1.73% and 1.6% of GDP in 2010), whereas the US is quite below: 0.77% of GDP in 2010, even far from the 1.28% of GDP represented by Chinese energy taxes in 2010 (OECD/EEA, 2013). For a general and updated assessment of energy taxation in the OECD see Harding *et al*. (2014).

In most countries taxes are levied on the main energy products and on some durables associated to energy consumption, namely vehicles. Yet table 3 shows that energy tax revenues may be highly concentrated in a few energy goods (as already depicted by figure 3 for the Spanish case), with a large reliance on car fuels taxes, which amounts to as much as 50% of final petrol and diesel prices in EU member states.

Actually, the EU framework for energy taxes (within the so-called harmonized European indirect taxation) has traditionally used minimum unit taxes that can be increased by member states and are subsequently subject to the general VAT. At the beginning of the 1990s, after the first Rio summit, the Commission attempted to modify this scheme by incorporating much higher tax rates on implicit CO_2 emissions and energy contents, known as 'ecotax', within the preceding unit tax structure. Although this was blocked by different countries and could not be applied due to fiscal unanimity rules, the European Commission

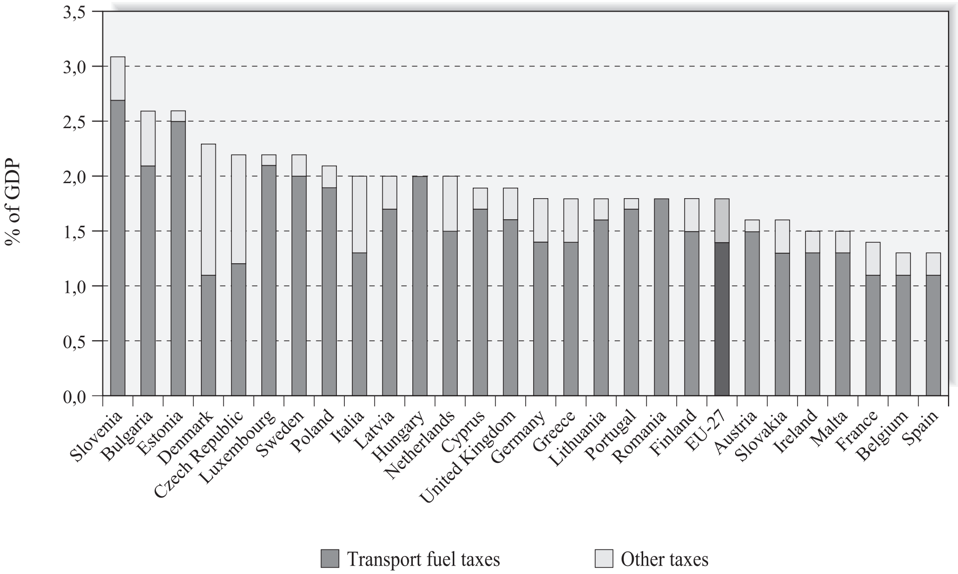

Figure 6. Energy taxes (excluding VAT) as % of GDP in Eu-27. 2011

Source: European Commission (2013) and the authors.

is now proposing a Directive with the same philosophy: harmonized European energy taxation would have a CO_2 component, linked to the EU emissions trading scheme (EUETS [12]) prices and thus leaving electricity exempt, and an energy component that would respond to revenue-raising and energy security matters. This general framework, quite related to the theoretical and design recommendations of previous sections, would include a gradual implementation and offsetting devices to protect European competitiveness.

Energy taxes in the EU, as in other developing and developed areas, are usually shared by different administrations. The relevance of subnational administrations in these matters is variable across countries, from mere revenue-sharing rules to capacity to design and/or regulate the main component of these taxes (see, e.g., Labandeira *et al*., 2009, for Spain). An enumeration of reasons for subnational approaches to climate policies can be found in Somanathan *et al*. (2014).

Energy taxation is structurally similar in other developed countries (IEA, 2013): Japan employs a tax scheme that is close to the EU except with automotive diesel (where the consumption tax is applied to the price before taxes), whereas Australia applies a national tax on liquid fuels used by households and state taxes are levied on natural gas and electricity. In the US there is a federal motor fuel (unit) tax, although sales of motor fuels to non-commercial users are generally exempt because motor fuel taxes also exist in many states and municipalities. There is no US federal tax on natural gas and electricity, although some states levy taxes on these goods.

Table 3
ENERGY TAXES AS % OF ENERGY PRICES IN SELECTED DEVELOPED COUNTRIES, 2012

	Light fuel oil (households)	Automotive diesel (non-commercial)	Unleaded gasoline (95 RON)	Natural gas (households)	Electricity (households)
France	22.2	47.2	54.9	16.6	31.7
Germany	22.9	47.5	55.6	23.8	45.5
Italy	45.0	52.9	57.5	37.6b	30.5
Spain	25.0	42.4	48.0	16.5	19.4a
United Kingdom	20.5	57.5	59.5	4.8	4.8
EU-21	27.4	48.5	54.6	21.5	26.5
Australia	n.a.	34.5	33.7	n.a	n.a
Canada	10.1	n.a	29.3	4.8	7.9b
Japan	7.1	30.7	42.8	4.8a	6.5
United States	4.7	13.4	13.6	4.8	n.a

Source: IEA (2013).
Notes: a: 2011 data; b: 2010 data; n.a.: not available.

Emerging countries do also use energy taxes with some intensity. India, for instance, has a variable VAT across states but a uniform excise tax throughout the country. As in the EU, VAT is levied on energy goods (including the uniform excise taxation) but can also contain an additional surcharge, whereas the excise tax contains both an *ad valorem* and a flat rate component with the former to the price excluding the dealer's commission (IEA, 2012). State taxes levied on the consumption or sale of electricity are also applied in different Indian states. China levies different taxes on vehicles, on the consumption of gasoline and diesel, and on the extraction of energy resources such as coal and natural gas. VAT is applied above those specific taxes, although at a lower rate for coal and natural gas (IEA, 2012). Many Chinese comentators have recently suggested that the role of energy taxes is likely to be reinforced in the next few years given the large attention paid by the current Five-Year Plan to climate change mitigation and to the use of market-based mechanisms to reduce GHG emissions (Guo and Zusman, 2010; Yuan and Zuo, 2011).

Oil-producing countries usually present a completely different (and opposite) approach to energy pricing, with a generalization of subsidies on most sources of energy (see e.g. Fattouh and El-Katiri, 2012). Table 4 shows the importance of these subsidies, which represented more than 50% of the costs of supply of energy products in 2011 and in several cases accounted for over 10% of GDP. Energy subsidies can be explicit (government spending) or implicit (revenue losses by failure to sell energy products at world prices) and cause a number of negative effects, such as a rise in energy intensity of GDP and low energy efficiency rates, a higher emission of pollutants, or negative distributional outcomes (see IMF, 2013). Although the lack of visibility of implicit subsidies and the popularity of generalized handouts make subsidy-removal harder, the economic and environmental costs associated to these schemes have prompted recent reforms in several countries such as Iran or Indonesia.

In any case, energy subsidies are not only an issue for oil-producing countries. They are employed in many countries, developed and developing alike, often in the shape of tax exemptions (Clements *et al*., 2014). These exemptions are often related to distributional concerns or/and the protection of the competitiveness status of certain sectors. However, they often collide with the environmental objectives and may even be counterproductive from a distributional point of view (see e.g. the distributional considerations of Section 3.2).

Table 4
ENERGY SUBSIDIES IN SELECTED OIL-PRODUCING COUNTRIES. 2011

	Average subsidization	Subsidy (% GDP)	Subsidy/person (US$)	Subsidy by fuel (billion dollars)		
				Oil	***N. Gas***	***Electricity***
Saudi Arabia	79.50%	10.60%	2,291.20	46.12	0.00	14.82
Iran	70.00%	17.00%	1,102.20	41.39	23.40	17.40
Kuwait	87.80%	6.30%	3,729.30	4.34	2.08	4.68
U. A. Emirates	69.10%	6.10%	4,172.10	3.93	11.52	6.37
Mexico	16.60%	1.40%	144.40	15.90	0.00	0.00
Russia	18.40%	2.20%	283.40	0.00	21.87	18.28
Algeria	50.70%	7.00%	372.20	11.26	0.00	2.13
Egypt	54.20%	10.40%	296.50	15.27	3.78	5.42

Source: International Energy Agency

3.3.2. *Energy tax-driven reforms*

In the last twenty years the applications of energy-related tax reforms have been mostly restricted to Europe. Several overviews of such experiences have been published, some of them quite recently (e.g. Speck and Gee, 2011; Speck *et al*., 2011; Gago and Labandeira, 2011; Bakker, 2009), which basically report two generations of green tax reforms (GTR) that would differ in both the guiding energy tax schemes and revenue-recycling procedures. We next describe the most representative applications within those generations.

GTR were born in Scandinavia in the early 1990s, with the core use of energy-related carbon taxes whose revenues were mainly devoted to income tax reductions. The first experiences had numerous exceptions for energy-intensive sectors to avoid their eventual delocalization to tax-free havens, which led to a tax focus on final consumers. These solutions were applied by Sweden (1991), which was soon followed by Norway (1992) and the Netherlands (1992). The latter introduced the general energy tax described in the previous section to increase fiscal, administrative and environmental effectiveness. More recently Estonia (2006) introduced a similar tax reform scheme, with substantial increases in energy taxes and similar reductions in income taxation. An epilogue to these experiences was, however, unsuccessful: in 2009 the French government tried to introduce a carbon tax whose revenues would be recycled through household direct payments (a 'green check'), but was opposed by a Constitutional Court that found the tax scheme unfair when compared to the EU ETS (due to its free allocation of permits).

A second generation of GTR was first defined by Finland in the late 1990s, with an emphasis in the increase of conventional energy taxes and a targeted reduction of labor taxes (i.e. social security contributions). Germany followed suite in 1999, with an ambitious tax reform that was centered on the extension and increase of energy taxes on final consumers and a subsequent reduction of social security contributions. However, the German GTR has not progressed as expected, probably due to public dissatisfaction on its perceived regressiveness and negative effects on competitiveness (despite empirical evidence on the opposite, see e.g. Ludewig *et al*., 2010). Moreover, a recent GTR carried out by the Czech government in 2008 has employed a similar scheme.

Finally, despite sharing some characteristics with the previous 'second-generation' applications, particularly the recycling of receipts in labor taxes, in the revenue-raising side the British GTR model has shown two important particularities with respect to the continental experiences: a wide use of non-energy related environmental taxes (e.g. landfill and aggregates taxes) and of energy taxes on commercial and industrial activities (e.g. climate change levy). Indeed, a recent tax increase of the climate change levy was not meant for revenue swaps but to provide additional funding for the public sector, thus advancing some of the trends that will be described in the following section.

4. A prospective for energy taxes

We have already mentioned that one of the objectives of this article was to provide some clues on the future developments of energy taxes and related tax reform packages. We feel that the new tendencies are to be explained, first, by a rapidly changing context. Indeed, the last few years have seen extremely deep changes in the economic outlook of most economies and societies that are contemporaneous to mounting environmental and energy-dependence concerns. We next provide an overview on such a changing environment before proceeding to describe innovative proposals and practices in energy taxation and energy-related tax reforms.

4.1. Shifting fiscal, environmental and energy contexts

This paper started by enumerating and analyzing the theoretical foundations of energy taxes, with revenue-raising needs, environmental correction and capture of resource rents seen as the main reasons for using these instruments. In the last few years, however, the fiscal, environmental and energy contexts have seen important changes. In this sub-section we intend to provide an overall picture of such developments, with obvious effects on the relative importance of the reasons guiding energy tax applications.

The great recession of 2008 and the subsequent economic downturn seen in most developed countries have had important effects on public revenues and expenditure. Figure 7a depicts sizeable public deficits in the major Western economies, brought about by the decreasing tax revenues associated to any economic crisis and the increasing (social protection) public expenditures. Given that energy taxes are usually less pro-cyclical than other fiscal mechanisms (e.g. corporate or income taxation), one should expect an increasing revenue pressure on these instruments. As this move would probably lead to a less progressive tax system, further demands of equity-conscious revenue recycling may also arise.

The world has also seen recent important changes in the environmental domain. Greenhouse gas emissions remain unchecked, as pointed out by the evolution of CO_2 emissions (dark gray line) in figure 7b. The black line in that figure represents the likely evolution of emissions, given the current set of corrective policies and instruments, and the light gray line the emission path that would be necessary to keep future temperature increases below 2ºC (as agreed in the Copenhagen and subsequent climate summits). Note that current actual emissions are basically following the red path, which would lead to very high temperature rises and to likely sizable environmental impacts and damages.

The preceding evolution of emissions responds to the absence of an effective international strategy to cope with this global problem. But if the lack of international credible climate change agreements generally reduces the environmental weight of energy taxes, there might be other collateral effects. It is thus possible that individual countries or a group of countries embark on climate change policies, either because the likely costs of inaction are very high [13] or because there are other significant (e.g. local) environmental problems associated to GHG emissions. It could even be the case that such move is done by a sub-national level of government. In such a setting, energy-related environmental taxes may be accompanied of border adjustments to protect competitiveness, and may also target those sectors that are the main contributors to the growing stock of emissions.

A third reason for energy taxes was related to energy dependence, which is behind the appropriation of resource rents by producers. Figure 7c illustrates the evolution of energy dependence in major European economies. If we match the evolution of energy dependence with the recent and prospective evolution of oil prices (figure 7d), the main source of energy-related rent exports, energy taxes are likely to play an increasing role in this area. Note that, as with CO_2 emissions, oil is following the high evolution path.

Finally, other diverse phenomena and factors are influencing energy tax developments. For instance, large public promotion schemes for renewable or energy efficiency technologies, which intend to tackle the double externality [14] associated to those technologies, are demanding increasing public funds precisely in a situation of acute shortages for public sectors. In such a situation, revenue-raising motives may play an ever-increasing role and fiscal reform schemes guided by energy taxes could face obvious difficulties.

Other less known factors may be also important. For instance, the development of new fiscal technologies may facilitate the introduction of figures that were deemed as unpractical only few years ago, such as car usage taxes. The growing complexity of energy and environmental (particularly climate) policies can also play a prominent role in the future development of energy taxes, so that negative interactions with other policy instruments are avoided or minimized. Finally renewed information on the distributional effects of energy taxes may also play an important role in future tax design and implementation, with growing evidence on their potential positive (or at least not so negative as previously reported) effects for developed and developing countries (see e.g. Sterner, 2012b).

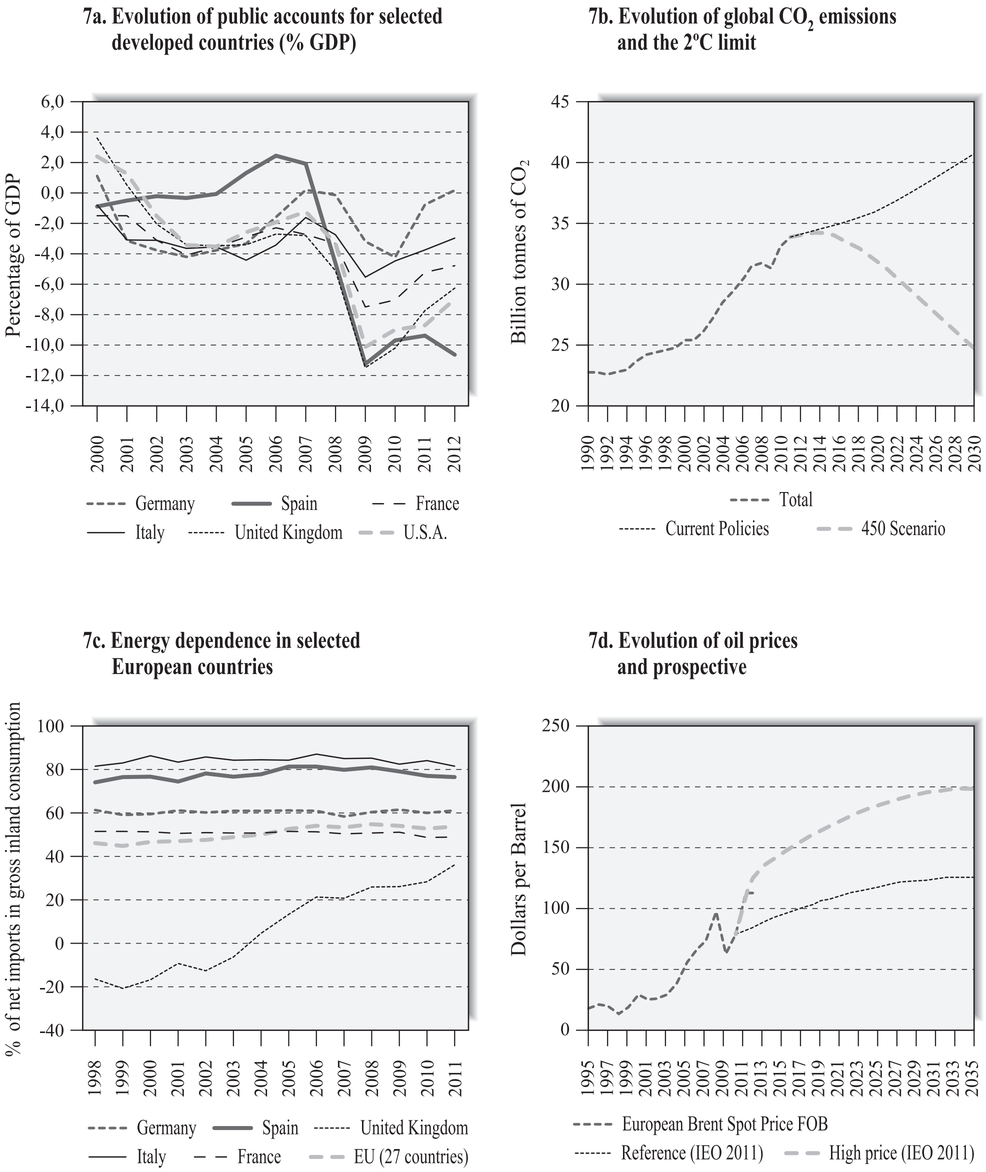

Figure 7. Fiscal, environmental and energy contexts

Source: a/ Eurostat and US Presidency; b/ Oliver *et al.* (2012) and IEA; c/ Eurostat; d/ US EIA.

4.2. Innovation in energy taxes and energy-driven tax reforms

The new context and trends described in the preceding section influence the specific applications of new energy taxes and, above all, the configuration of a new generation of GTR. In the next sub-sections we deal with both issues.

4.2.1. *New energy taxes*

A shifting economic, fiscal, energy and environmental context has generated a wide array of new proposals in the field of energy taxation during the last few years. We now provide some information and reflections on four instruments that reflect such a changing atmosphere and may play an increasing role in the future: border tax adjustments, carbon added taxation, taxes on energy inefficiency and new car taxes. Bear in mind that this subsection does not intend to review, in an exhaustive manner, all new possibilities in this fiscal domain but rather to yield some light on some representative options.

Border tax adjustments: We already mentioned the challenges faced by countries that want to mitigate GHG emissions in absence of a full and global international agreement, and how border tax adjustments (BTA) could be used in this setting (see Section 4.1). As GHG emissions are largely caused by energy production and consumption, a BTA discussion is relevant in this section. Indeed, BTA can protect industrial activities that are subject to a national or supranational (but incomplete) climate policy regime, but can also guarantee that climate policy objectives are achieved [15]. BTA actually modify the price of imported and exported products through tariffs and tax refunds to equal their climate tax burden. Therefore, BTA should not be viewed as a barrier to trade; rather, the absence of a carbon price constitutes an implicit subsidy to polluting production in unregulated markets (Helm *et al*., 2012). In that sense, we can interpret BTA as a tax on emissions consumption (Mattoo and Subramanian, 2013).

However, practical difficulties for the application of these instruments abound. The literature has shown considerable advances, by progressing from a general and universal BTA (Courchene and Allan, 2008) to more selective proposals that would be applicable to wide groups of products with equivalent carbon contents and to the use of automatic standard tax rules (McLure, 2010). Others suggested a less casuistic approach by using general averages (Holmes *et al*, 2011) or by calculating BTA from data of the most carbon efficient European facilities (Monjon and Quirion, 2010). In this sense, Metcalf and Weisbach (2009) and Weber (2011) have provided two proposals that complete the previous framework: the former with a 'presumptive' BTA that would also use average emissions from exporting countries, and the later with a 'virtual' BTA that would calculate adjustments through standard input-output techniques.

Carbon added taxation: A carbon added tax (CAT) would be levied on the addition of carbon in each phase of the productive process, therefore resembling VAT in its functioning and structure (Laurent and Le Cacheux, 2010). It is quite possible that this tax proposal responds again to the challenges of unilateral climate policies, as described in the BTA discussion, because it would relate with hypothetical BTA in a nice and consistent manner. A downstream CAT could also solve some of the problems associated to upstream carbon taxes, already mentioned in Section 3.1, avoiding excessive cost-pass through of the tax and improving the reaction of agents to the instrument. Of course there are difficulties for the practical implementation of CAT, mostly related to the required assessment of the added carbon in each productive phase (Cockfield, 2011).

Taxes on energy inefficiency in buildings: In Section 4.1 we mentioned that some sectors were crucial to control present and future energy demand and, therefore, energy-related emissions and dependence. This is the particular case of buildings, mostly due to the irreversibility of emissions once the building is operative. In a recent paper Gago *et al*. (2013) suggest that, due to a number of general and specific barriers to the implementation of energy efficiency in buildings, energy prices and conventional energy and environmental policy instruments may not achieve the desired outcomes. They thus propose a package of complementary measures that would simultaneously tackle the problems of imperfect information, split incentives among agents, uncertainty about cost and limited access to capital. The package would be defined around energy certification of buildings, would use flexible building codes, smart metering and would particularly employ a new tax on energy inefficiency to foster continuous incentives towards energy efficiency improvements and to obtain revenues for an energy efficiency fund that provides capital to firms and poor households. In particular, the energy inefficiency tax would use existing tax information on the property size (i.e. would be administratively feasible) that would be complemented with an increasing tax rate on the energy certificate of the building.

New car taxes: A transition to cleaner cars (e.g. electric or hybrid automobiles) would have, first of all, important revenue costs for public sectors. This was clearly observed in figure 6 and table 3, as car fuels are an important source of receipts in European countries (and elsewhere). This, added to the persistence of sizable externalities associated to private transport, would recommend the definition of a new tax regime for cars. There have been numerous proposals to design new taxes on car mileage or, better than that, car usage (CUT), without the need of employing proxy approaches such as those described in Section 3.1. Local environmental emissions, congestion and infrastructure use, among other things, could be simultaneously tackled with a CUT, which would also be a potential source of sizable public revenues. As hinted before, we have now the technological capabilities to introduce this fiscal innovation with a generalized use of GPS devices (Phua, 2011). Several questions remain, however, on how to organize an efficient transition from actual systems and how to ensure protection of confidential and rather sensible personal information on car uses.

4.2.2. *New energy-driven tax reforms*

Growing revenue needs for many public sectors due to a persistent economic recession or stagnation, increased crisis-related competitiveness and uncertain distributional concerns, and the growing costs of renewable and energy-efficiency promotion in many countries are, among other things, all having an important influence on the practical configuration of new GTR. Indeed, the new applications show, for the first time, a departure from the standard 'double-dividend' reasoning (see Section 2.4) that strongly informed and influenced GTR before the outbreak of the economic recession.

In this new setting a third generation of GTR is being conformed, with a number of experiences that in essence share more flexible and heterogeneous revenue uses. Italy advanced this trend in the early 2000s by devoting a third of the revenues of its GTR for distributional compensatory measures and the promotion of energy efficiency. A recent proposal by the Italian government insists in this course by introducing a carbon tax whose revenues would be primarily earmarked to the promotion of low-carbon technologies and procedures (Shaheen, 2012). Even Sweden, the origin of GTR, can be now incorporated to this generation as its 2002 'Green Tax Shift Program' involved the use of increased tax revenues for fiscal consolidation.

The third generation also includes an Irish application that, in the middle of an intense economic crisis, used carbon taxation with fiscal consolidation purposes (i.e. without revenue recycling) (see Convery, 2010). Switzerland also introduced a carbon tax in 2008 with mixed revenue recycling: transfers and specific tax exemptions to firms and citizens and funding of energy efficiency improvements in buildings (FOEN, 2010). But perhaps Australia has yielded one of the most interesting and relevant recent experiences with GTR. Its recently approved Climate Policy Program establishes a carbon tax whose revenues are used to reduce income taxes, fund renewable and energy efficiency investments, and to protect industrial competitiveness and R&D efforts.

Finally, although no actual applications have been rehearsed so far, there is an increasing interest in the implementation of GTR by some emerging and developing countries (see Heine *et al.*, 2012). These tax reform packages could contribute to a better environmental performance, especially needed given the growing climate change concerns and acute local environmental problems in the developing world, and could also attain a fairer (as already mentioned in Section 3.2, given the progressivity of fuel taxes) and more efficient tax system.

5. Conclusions

This survey has dealt with the foundations, practical experiences and prospective of energy taxes, providing, at the same time, some reflections on the probable future evolution of these taxes and related tax reforms. The article suggests that the theoretical reasons behind energy taxation have had different relative importance across the time, probably due to a shifting economic, fiscal and environmental context. Nowadays revenue-raising motives are playing an increasing role due to the decreasing conventional tax revenues and growing expenditure needs that are related to the current economic downturn faced by many advanced countries. Yet stagnant energy-dependency and energy-intensity ratios, coupled with a rising oil price, also increase the rent-capture role of energy taxes. Environmental reasons, particularly those related to GHG emissions, are at the moment less important due to the mounting difficulties to reach global agreements in this matter, but they are likely to be relevant in the tax policy making of many countries. Such a disparate and heterogeneous group of theoretical reasons behind energy taxes is sometimes difficult to transfer to practice. But even when that is possible, the existence of trade-offs and negative interactions may abound.

Moreover, the paper has paid a strong attention to the practice of energy taxes and environmental tax reforms, with an overview of the existing empirical literature and a selection of some specific and systemic applications across different countries of the world. We feel that the paper thus contributes to the academic literature by presenting a comprehensive theoretical and practical framework on energy taxes, and may be also useful for policymakers and scholars interested in the use of these fiscal instruments in the energy domain.

Yet, one of the main novelties of the article is probably related to the reflection on the present and future foundations and experiences of energy taxation in a particularly shifting world. Indeed, a changing economic, environmental and energy atmosphere indicates that both specific and systemic applications of energy taxation are likely to evolve in the future. The article suggested that border tax adjustments, carbon added taxation, taxes on energy inefficiency and new taxes on cars might play a significant role in the future. Besides, a new model or generation of GTR is taking shape, with a departure of the standard 'double dividend' foundations through the use of tax revenues for, among other things, funding energy efficiency/renewable programs or distributional offsets. The analyses of the preceding issues, together with a much-needed attention to the behavioral insights associated with energy taxes and tax reforms (see e.g. Pollit and Shaorshadze, 2013), are likely to provide interesting and useful avenues for research in the near future.

Annex

Table A.1.
DESCRIPTION OF VARIABLES INCLUDED IN THE ESTIMATION

		END	ENP	GDP	EMP	WEL	CPI	CO2
Model dummies	Bottom-up (BU) model	0	2	0	0	0	0	20
	Input-output (IO) model	0	3	0	0	0	0	0
	Macroeconomic (MACRO) model	13	12	77	71	0	43	89
	Partial equilibrium (PE) model	40	9	30	30	0	30	47
	Static general equilibrium (SGE) model	75	23	93	75	77	35	115
	Dynamic general equilibrium model	54	13	203	66	52	29	207
Dummies for country characteristics	- *Energy dependence*							
	Energy exporting country	25	9	96	52	35	28	102
	Energy importing country	157	53	307	190	94	109	376
	- *Developmental level*							
	Developed country	162	47	300	219	113	115	357
	Developing country	20	15	103	23	16	22	121
Dummies for government level	Central government	39	49	145	99	68	39	190
	Other levels of government (regional or supranational)	143	13	258	143	61	98	288
Dummies for tax characteristics	- *Type of energy product taxed*							
	Electricity	14	7	6	3	0	2	5
	Natural Gas	16	2	4	4	5	2	10
	Oil products	33	17	14	12	6	2	33
	Coal	16	6	5	4	2	2	8
	All energy products	107	30	382	227	123	133	441
	- *Type of tax base*							
	Consumption tax	173	56	372	228	116	135	437
	Production tax	9	6	31	14	13	2	41

Source: The authors.
Note: Figures in the dummies rows indicate the number of observations of each characteristic in each of the estimations.

Table A.1. (*Continued*)
DESCRIPTION OF VARIABLES INCLUDED IN THE ESTIMATION

		END	ENP	GDP	EMP	WEL	CPI	CO2
Dummies for green tax reform (GTR) characteristics	GRT via reduction of social security contributions (SSC)	55	23	142	139	51	105	175
	GRT via reduction of income tax	34	6	59	49	11	40	56
	GRT via reduction of VAT	9	7	23	11	9	7	20
	GRT via reduction of corporate tax	3	5	11	6	3	4	9
	No GRT	81	21	168	37	55	15	218
Tax rate	Mean	0.1141	0.2524	0.1942	0.2139	0.1410	0.1920	0.2020
	Standard deviation	0.1903	0.3291	0.2424	0.2191	0.2111	0.1415	0.3103
	Minimum	–0.8522	0.0103	–0.2385	0.0004	0.0004	0.0068	–0.2385
	Maximum	1.0544	1.4349	2.2400	1.4550	1.0544	0.9672	2.6675

Source: The authors.
Note: Figures in the dummies rows indicate the number of observations of each characteristic in each of the estimations.

Table A.2.
PARAMETER ESTIMATES. META-ANALYSIS

	Energy demand	Energy prices	GDP	Employment	Welfare	CPI	CO_2 emissions
$\hat{\beta}$	-0.0379**	0.2934*	-0.0016	-0.0037	-0.0004	-0.0079	-0.1482***
Dummy SGE model	0.0071	-0.2530**	0.0044***	-0.0034*	-0.0014	-0.0008	0.0465***
Dummy MACRO model	0.0156	-0.2334	0.0066***	0.0008	-	0.0002	0.0129
Dummy IO model	-	-0.0331	-	-	-	-	-
Dummy PE model	-0.0373***	-0.1492	0.0054**	0.0114***	-	0.0087**	-0.0108
Dummy BU model	-	-0.2269*	-	-	-	-	-0.0117
Tax rate	-0.2649***	1.0688***	-0.0056**	0.0068***	-0.0096	0.0051	-0.1539***
Dummy exporting country	-0.0084	0.2744**	-0.0026***	-0.0027**	0.0009	0.0002	-0.0222**
Dummy developed country	-0.0098	0.1489**	0.0029***	0.0029	-0.0006	0.0170***	0.0781***
Dummy central government	-0.0273***	-0.2832*	-0.0047***	-0.0001	-0.0016	0.0074	-0.0104
Dummy electricity	-0.0031	0.0765	0.0013	0.0041***	-	-0.0055	-0.1109
Dummy natural gas	-0.0123	0.1207	0.0008	-0.0051	0.0896***	-0.0029	-0.4384***
Dummy oil products	0.0331***	0.1530	0.0016	0.0067*	0.0010	-	0.0896***
Dummy coal	0.0181*	0.7397***	-	-	-0.0783***	-	0.2535***
Dummy consumption tax	0.0490***	-0.0258	-0.0031	0.0006	0.0011	-	0.0110
Dummy GTR via SSC	-0.0000	0.0147	0.0047***	0.0074***	0.0079***	-0.0086**	-0.0015
Dummy GTR via Income tax	-0.0190	-0.1217	0.0006	0.0001	0.0007	0.0070***	-0.0233

Source: Own calculations.
Note: We indicate significance by *** at the 1% level ** at the 5% level and * at the 10% level.

Table A.2. (*Continued*)
PARAMETER ESTIMATES. META-ANALYSIS

	Energy demand	Energy prices	GDP	Employment	Welfare	CPI	CO_2 emissions
Dummy GTR via VAT	-0.0464***	-0.0181	0.0017	0.0025	0.0041	-0.0074	-0.0357
Dummy GTR via Corporate tax	0.0238	-0.0583	0.0027	-0.0071*	0.0031	0.0002	-0.0508
Sample size	182	62	403	242	129	137	478
Test of joint significance	F(17,144)=75.58 p-value-=0.0000	F(19, 36)=178.67 p-value-=0.0000	F(16, 350)=21.21 p-value-=0.0000	F(16, 193)=15.54 p-value-=0.0000	F(13, 47)=25.27 p-value-=0.0000	F(14,111)=33.59 p-value-=0.0000	F(18, 441)=45.97 p-value-=0.0000
R-squared	0.8628	0.8638	0.4198	0.5538	0.8720	0.7802	0.4262

Source: Own calculations.
Note: We indicate significance by *** at the 1% level ** at the 5% level and * at the 10% level.

Notes

1. Even though energy tax revenues have shown signs of stagnation in some developed countries during the last few years (see e.g. European Commission, 2013), probably related to the effects of energy and environmental policies on energy demand, energy tax rates are likely to maintain an increasing trend both in the developed and developing world. Figure 6 shows the relevance of energy tax revenues in the EU.
2. Zajac (1974) extends this result when cross-product price elasticities are not null. In that case public revenues should come from the taxation of all existing goods following the difference between prices and unit variable costs when firms maximize profits.
3. Even though the preceding section indicated that taxing final consumers would avoid productive inefficiencies, in this case the existence of a negative externality (i.e. preventing an efficient outcome) justifies the introduction of a tax on producers with corrective purposes.
4. Note that marginal external costs are likely to vary with the level of emissions and therefore using standard damage estimates is usually suboptimal.
5. This may be less problematic in cases when the marginal external cost curve is highly elastic in the short term, such as with greenhouse gas emissions or mortality-related local pollutants, and when some externality measurements exist (Heine *et al.,* 2012).
6. This is explained by the fact that polluters, despite having information on their abatement cost structures, are not interested in revealing them to the regulator as this might bring about stricter requirements. The regulator, on the other hand, has limited information on the technical possibilities of abatement by the numerous polluters and also limited resources for an eventual assessment and inspection.
7. See Markandya *et al.* (2014) for a discussion of the role of energy taxes to foster energy efficiency.
8. In this sense, all simulations were considered to analyze the effect on energy prices and welfare (62 and 129, respectively). Moreover, 182 simulations (of 235 employed for figure 4) were considered to compute the effect on energy demand. For the remaining variables, the considered simulations are in a wide range: 403

(GDP), 242 (employment), 137 (CPI) and 478 (CO_2 emissions), over a total of 547 (GDP), 287 (employment), 145 (CPI) and 656 (CO_2 emissions) of those used to draw figures 4 and 5.

9. These can be bottom-up, input-output, macroeconomic, partial equilibrium, static general equilibrium or dynamic general equilibrium models (see, e.g., Gago *et al.,* 2004)
10. The detailed results of the estimation are provided in the Annex.
11. There seem to be no relationship between per-capita GDP levels and higher energy taxes (as a proportion of GDP): some affluent European countries such as Denmark or Sweden have sizable energy taxes but so do other less wealthy members like Slovenia or Bulgaria. This might be related to explicit environmental concerns in the former and to general fiscal constraints in the latter.
12. An analysis of emission trading schemes is clearly beyond the scope of this paper but it is worth noting that they, as market-based instruments, share many of the properties of environmental taxes. In the case of the EUETS this is reinforced by the recent moves towards full auction of permits (see Ellerman *et al.*, 2014).
13. Most experts believe that the window of opportunity, to keep global average temperature increase below 2ºC, is now closing. Figure 7b illustrates the build up of a growing emissions gap (the difference between black and light gray lines). As most GHG emitters have a strong stock component (i.e. they would contribute to emissions for a long period), strong and immediate actions are necessary.
14. That is, external effects with a simultaneous environmental and technological nature (see Newell, 2010).
15. This can be done by reducing emission leakage and by sending the right price signals for final consumption. Regarding the latter, unilateral climate policies without BTA may appear effective when computing production-based carbon emissions but are usually a failure when assessing consumption-based emissions [a UK assessment of this issue can be found in Druckman and Jackson (2009), while Wiedmann (2009) provides a survey of studies that estimate consumption-based emissions].

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Resumen

Este artículo proporciona una visión general de las aplicaciones específicas y sistemáticas de los impuestos sobre la energía y las reformas fiscales verdes. Para ello combina una evaluación teórica y empírica de la literatura con una descripción no exhaustiva de la práctica de estos instrumentos y paquetes en el mundo real. Además de proporcionar una aproximación integral al uso específico y sistemático de los impuestos sobre la energía, el trabajo contribuye a la investigación en esta área reflexionando sobre el presente y el futuro de estos instrumentos en un mundo particularmente cambiante.

Palabras clave: Impuestos, energía, medio ambiente, externalidades, recursos naturales.

Clasificación JEL: H21, H23, Q48, Q58.