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Abstract

In this paper we focus on the reasons why progress in terms of realizing the energy efficiency potential has been so limited. To being with we consider why individuals and firms do not take advantage of the benefits of increased energy efficiency. Then we turn to the role of policy in moving agents closer to the optimal level. Governments have a range of instruments at their disposal for doing so and while some of them have been successful other have not. Lessons can be learnt from the experience in implementing these different measures. The paper finishes with some thoughts on how policies can be made more effective. Given its overarching nature the paper should be seen as an introduction to the rest of the book where many of the different instruments for energy efficiency are discussed in greater detail.

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1. Introduction

An important part of the actions required to move to a low carbon economy is an increase in the amount of economic output we get out of a unit of energy – i.e. an increase in energy efficiency. A recent report from the European Parliament for climate end energy policies (EP, 2014) notes that the EU has a cost-effective potential for energy saving achieved through energy efficiency of 40% in the whole economy (61% from the residential sector, 41% from transport, 38% from the tertiary sector, and 21% from industry). It also notes that a significant percentage of this has not been realized – 80% in the case of the residential sector and 50% in the case of industry. This difference between the real level of investment in energy efficiency and the "economically optimal level" as defined in various studies such the one mentioned above is referred to in the literature as the Energy Efficiency Paradox (Jaffe and Stavins, 1994).

In this paper we focus on the reasons why progress in terms of realizing the energy efficiency potential has been so limited. To being with we consider why individuals and firms do not take advantage of the benefits of increased energy efficiency. Then we turn to the role of policy in moving agents closer to the optimal level. Governments have a range of instruments at their disposal for doing so and while some of them have been successful other have not. Lessons can be learnt from the experience in implementing these different measures. The paper finishes with some thoughts on how policies can be made more effective. Given its overarching nature the paper should be seen as an introduction to the rest of the book where many of the different instruments for energy efficiency are discussed in greater detail.

2. How Rational are Individuals in Their Use of Energy?

At the outset it helps to define the economically optimal level of energy efficiency more precisely. From an economic perspective measures should be pursued to increase energy efficiency to the point at which the costs of further efforts in improving it are equal to the benefits. In this definition the costs are to be seen as the social costs and the benefits as the social benefits (as opposed to the private costs and benefits). This distinction is important because an individual will only seek to achieve efficiency to the point at which private costs and benefits are equalized. The social and private benefits diverge because energy use creates externalities such as local and global air pollutants. So even if the agents in an economy were to realize their full net gains from such actions they would not undertake enough effort in increasing energy efficiency.

But in practice agents do not even equate the private benefits of more efficient energy use to the costs and understanding the reasons for that are important. Why do we not, for example, switch off devices such as TVs when the savings in energy are significant and costs minute? Or buy energy efficient light bulbs when all calculations indicate that they are more cost effective then incandescent ones? Indeed, the researchers have found that individuals discount the future very highly and that the estimates of energy efficient choices are based on lower rates. Studies of choices for energy efficient refrigerators in US, for example, indicate that consumers' mean discount rate is about 39%, with a normal distribution around that mean, and standard deviation of 18.7 (Revelt and Train (1998)). The literature gathers these situations under the so-called Energy Efficiency Paradox, and provides a number of reasons that explain it (see e.g. Linares and Labandeira, 2010). First perhaps is the fact we individuals are not always rational. When facing difficult decisions we apply simplified approaches that are easy to implement. Acting rationally can involve a lot of information processing and when the costs of dealing with the many decisions are taken into account some of the so-called non-rational actions look rational (Gillingham and Palmer, 2013).

Other factors that can explain the apparent lack of even limitedly optimal self-interest behavior at the individual level include: (a) lack of knowledge about energy saving measures (b) capital constraints, which make it difficult to acquire equipment that is more energy efficient[1] (c) time preference (d) the principal-agent problem and (e) uncertainty about the effectiveness of the measures[2]. These points have been discussed a lot in the literature, going back to the Jaffe and Stavins 1994 paper and need not be repeated again in detail. Perhaps a few words may be said about some of the less well-known ones. Some studies have focused recently on estimating the existence and the magnitude of the principal-agent problem (Davis, 2012). This situation happens, for example, in the case where renter decisions about energy use are taken by her and she pays the bills but the decisions about the equipment installed are taken by the owner, who goes for the cheapest alternative. Thus, in this case the most cost efficient combination may not be chosen (IEA, 2007).

In terms of policy the implications from this literature are clear at least in terms of what we need to change. Better information, possible access to up-front capital, loans at subsidized rates and regulations that specific efficiency standards in certain cases emerge as possible measures. These have been tried to various degrees and we discuss them in the later sections. Another line of reasoning that has been followed is to change some less rational behavior through "nudges" and other measures where we appeal to other factors. These can include the following:

- Smart meters: provide more information on use and allow you to program use accordingly.
- Comparison with neighbors about use rates (how you compare with the average and with the most efficient).
- DIY meter that glows if you are using more energy than normal (UK).
- Power aware cords for appliances. They glow if a light has been left on for long.

[1] Surveys carried out by the OECD and others indicate that economic considerations such as the full price (i.e. levelised costs including capital plus operating costs) are not as important as capital costs and labelling of products when making energy appliance choices (Ščasný, M., Urban, J., 2009).

[2] There is also a literature which notes that that measures of the energy paradox are exaggerated because the methods used do not take account of the fact that consumers have different preferences. See for example, Bento, Li and Roth (2010).

There is limited anecdotal evidence but no full review of how effective such measures are (except work on smart meters which questions their cost effectiveness, see e.g. De Castro and Dutra, 2013). Indeed given the limited evidence on the effectiveness of such measures their popularity in some public debates about the way forward may be, in our view, misplaced.

3. Measures to Improve Energy Efficiency

The discussion in the previous section leads us to consider the different instruments for improving energy efficiency and getting as close as possible to the socially optimal level. As noted, this requires more than getting individuals to achieve their private optimality goals. The presence of externalities means that further increases in efficiency are justified.

Summaries of the research on energy efficiency policies can be found in a number of publications (see for example Geller et al., 2006; IPCC, 2007; EC, 2011; OECD, 2003; IEA, 2011, 2008). What this paper offers in addition is: (a) an update from recent publications on instruments and (b) our interpretation of the areas where the conclusions are perhaps misleading and where we need further work.

The policies and measures at our disposal can be put into broadly three categories. The first consists of direct intervention through public policies that establish minimum standard levels and mandate certain technical requirements that increase energy efficiency. The second are the group of instruments that work through ‘price’ incentives, e.g. in the form of subsidies or charges or other financial costs of energy to the consumer or producer. Lastly we have schemes that seek to improve knowledge of energy related issues, such as use of appliances, existence of efficient methods of using energy etc. Table 1 shows examples of each policy carried out by several European countries.

3.1. Command and control approaches

Governments can require manufacturers to produce energy products and services with a minimum level of energy performance. Usually these policies are materialized through codes and standards. Some examples are construction codes for building sector, minimum standards for automobiles and appliances, or small-scale combustion plans for industrial sector. These legislative or normative measures are characterized by their low flexibility, which in some cases can generate considerably high implementation costs (Galvin, 2010). The rigidity originated by the absence of any alternative in the market can make some agents, for whom the costs of applying such measures are very high, to leave the market. Consequently, governments should carefully determine the minimum level that achieves the maximum savings at the lowest cost for the whole society.

Table 1. Summary and examples of the most common energy efficiency policies in Europe

Classification	Energy efficiency policy	Example	Country	Sector
Command-and-control	Codes	Building codes	France	Household, Tertiary
	Standards	Emission performance standards for new passenger cars	Germany	Transport
Price instruments	Taxes	Motor vehicle duty (with CO_2-based components since 2009)	Germany	Transport
	Subsidies	CHP grants program (private sector)	Ireland	Tertiary
	Tax deductions	VAT deduction in energy efficiency investment	France	Household
	Credits	Energy saving loans	Norway	Household
	Permits	EU-ETS	Germany	Industry
	Tradable Obligations	White certificates	Italy	Household, Tertiary, Industry.
Information instruments	Labels	Energy performance certificates for buildings	Spain	Residential, Tertiary
	Audits	Compressed Air Efficiently –the PATE audit model	Finland	Industry
	Smart meters and billing information	Smart metering and billing for SMEs	UK	Household Tertiary

Source: Project ODYSSEE-MURE

While these energy efficiency policies are adequate to reach minimum energy savings, they might not be the most cost-effective way to achieve higher levels of energy savings. Hence, codes and standards can play a key role in developing economies where there is a large potential for low cost energy saving investments. There is also the issue of a "rebound effect" when energy efficiency is increased but the increase in effect lowers the cost of operating the device or equipment where the gain takes place. The lower cost results in an increased demand for energy, negating in part the effect of the gain. We discuss this further below.

3.2. Price instruments

In contrast with command-and-control measures, price or economic instruments have the objective to encourage or discourage certain economic decisions by indirect changes in prices. Thus, public authorities can use taxes and permits to penalize energy consumption, and subsidies and tax deductions to stimulate energy savings. They are usually applied on CO_2 emissions or energy consumption but may also take the form of tax relief on appliances, loans at preferable rates etc. Although these measures are also subject to important limitations, they are characterized by a higher degree of flexibility in the way that the energy sector can respond to the measure.

Taxes have traditionally been one of the most common instruments used by energy and climate change policies to control energy consumption. They have been mainly applied directly on consumption, and one of their advantages is the capacity to generate tax revenues that can be then redirected with energy efficiency and distributional purposes. Some examples of taxes are acquisition taxes for automobiles and electricity and fossil fuels taxes in the residential sector. At the same time, governments have also introduced a large variety of direct subsidies and tax deductions for energy efficiency investments in all sectors of the economy. Moreover, some governments have also approved low interest loans to help financing such investments, and particularly ESCOs[3].

As noted these interventions are also exposed to important limitations. First, in many cases they raise energy prices, which are politically sensitive, partly due to our experience of the volatility in oil and gas markets. There is a major concern about energy (or fuel) poverty that limits the scope for increasing prices as a policy tool, although there is also evidence that the impacts of some increases on income distribution are exaggerated. In developing countries the case for fuel taxes is opposed on distributional grounds but as Sterner (2011) has forcefully shown the main beneficiaries of lower prices are not the poor but middle and upper income groups. It is also argued in the literature that the impact of raising energy prices on energy consumption is small as the price elasticity for different kinds of energy is very low in the short run and general low in the long run (Gillingham et al. 2009). The evidence on this, however, is contested. While most researchers would agree that the short-run demand is inelastic with respect to price there is some evidence that in the long run the elasticity is considerable and often well over one (Sterner, 2007). Moreover the estimates have a wide range, indicating that response to taxes may well vary by location (Espey, 1998).

The other fiscal incentive of course is to provide some kind if subsidy and there are many schemes of this kind that have been tried. In general they do result in the adoption of more energy efficient appliances and they are politically popular but they have a number of negative aspects. One is the high fiscal cost of providing the subsidy. Second is the scope for misuse of funds when a subsidy is being offered. Third we have the rebound effect, so the reduction in the price of an appliance results in consumers buying larger and more energy-using versions. For all these reasons subsidies often turn out to be a high-cost policy for achieving energy efficiency (Jaffe et al. 2004). We provide a more detailed comparison between taxes and subsidies in the next section.

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[3] Energy Services Companies (ESCOs) are companies that guarantee the energy savings by energy performance contracting, that is, customers pay the services with the energy savings achieved.

A dual approach to fiscal incentives is to use permits rather than taxes and subsidies and there a number of cases of such approaches in Europe and the US, the largest perhaps being the EU emission trading scheme (EU ETS) for GHG emissions created in 2003. By limiting the number of allocated permits the authorities can reduce emissions and provide incentives to increase energy efficiency. Since the permits are tradable, agents with a low cost of reducing emissions can make bigger cuts then their allowances demand and sell any surplus to those agents who face higher costs. In this way the overall cost of meeting a given target reduction is minimised. The EU ETS is discussed elsewhere and we do not go into depth on it, except to note that its effectiveness in including energy efficiency gains is clearly dependent on how many permits are issued, on how they affect energy prices and by the interaction between the ETS and other schemes. The EU ETS has been facing significant problems that are related to the preceding matters but, as indicated above, they are beyond the objectives of this paper.

The use of trading to allocate efficiency targets has been used in other contexts of energy regulation as well. One of the latest and most innovative policies to promote energy efficiency is the introduction of obligations or white certificates systems. This legislative measure requires energy suppliers to achieve a fixed amount of energy saving by applying certain measures of energy efficiency on their final customers, during a limited period of time. In some cases, the level of energy savings is certified by public authorities through the so-called white certificates, which can be traded so an overachievement of a target can be sold to someone who is underachieving his target. Hence, similarly to permits, obligation systems represent a flexible approach that encourages cost effectiveness.

This mechanism has been applied recently in Italy, UK, France, Denmark and the Flemish region of Belgium. The design of the policy varies for each country depending on the obliged party, the number of involved sectors, and on the measurement of energy savings. Bertoldi and Rezessy (2009) and Bertoldi et al. (2010) provide a detailed description of such systems. While there are many positive aspects to such an approach, there has been concern with the possible interactions with the EU-ETS in Europe, and with the existence of rebound effects (see below).

3.3. Information instruments

Information policies have the goal of mitigating the negative effects of incomplete information, one of the most important market failures in this area. During the last few years governments and energy agencies have introduced a number of different mechanisms to provide customers with direct, cheap and reliable information about the energy performance of their energy services and products. Some examples of these were presented in the previous section (see Section 2).

Such information can be provided in different formats, depending on the sector of the economy. One of these is energy performance certificates or labels, which were first used in other areas such as the food industry. More recently, they were used in the energy efficiency market for products like vehicles, buildings, or appliances. These labels or certificates have the objective to provide consumers with information regarding the energy performance of such products. Most importantly, they generally classify that level of energy performance in relation to the rest of products in the market so that consumers can then compare them. In the US the *EnergyStart* is a voluntary program that distinguishes high-energy performance products such as buildings, appliances, electric equipment, etc. In Europe, the Energy Performance of Buildings Directive (Directive 2010/31/EU) requires the owner to show an energy performance certificate when any building is rented or sold. Directives 1997/94/CE and Directive 92/75/CEE revised in 2010 (Directive 2010/30/EU) replicate this with vehicles and appliances, respectively.

Regarding the industrial sector, the most common information instrument is energy audits. Some governments perform free-of-charge energy audits for a group of industries with the objective to spread the results among the correspondent industrial branch, while others simply help financing energy audits.

Finally, as noted in the previous section, some governments and regulatory commissions are also approving specific legislation to guarantee the introduction of other innovative informational mechanisms that have been found to achieve some energy savings in the residential sector. In particular, these mechanisms consist of smart meters that help consumers to know their own consumption in real time, and billing information that includes a comparative analysis of their own consumption with that of a similar consumer. In particular, billing information uses social norms to change the habits or behavior of consumers towards more energy-responsible patterns (Schultz et al., 2007). The following section shows some examples of this approach.

4. Evaluating the effects of policies

In this section we present some of the key findings relating to the effectiveness of the different policies described above. Given that a number of them have only recently been introduced it is not possible to undertake a comprehensive *ex post* assessment and the jury is still out as to how effective they are. In such cases we can only comment on issues relating to the implementation of the programs and on some surveys that have been conducted during implementation.

4.1. Codes and Standards

Since codes and standards have been applied for many years, the market has already generated a sufficient amount of data that allows analysts to evaluate these policies *ex post,* using real data.

In the case of transport, the data show that despite the improvements on fuel consumption levels due to standards, final energy consumption from transport sector has continued growing due to an increase of the size of vehicles that have outweighed the previous effect (Wesselink et al., 2010). The rebound effect is thus particularly important here and estimates indicate that a 100% increase in energy efficiency can result in an increase of about 22% in energy demand (Sorrell, 2007). Other authors as Frondel et al. (2008) find even higher rebounds, in the 50-60% range.

In the case of the residential sector the evidence of such an effect is much less evident. Aroonruengsawat et al. (2012) found that those states in the US that had adopted building codes before an increase in construction had reduced their per capita electricity consumption from 0.3 to 5% in 2006. Other studies find mixed evidence on the effectiveness of the measures in terms of reductions in energy (Sorrell, 2007). There is also recent work indicating that increases in energy efficiency via technical improvements may have a “macroeconomic” rebound effect as well by lowering the price of energy because of the shift in the demand curve, which in turn increases demand elsewhere (Gillingham, Rapson and Wagner, 2014). This effect for some autonomous energy efficiency improvements could be quite significant.

While several studies measure this rebound effect very few carry out a cost effectiveness analysis of the codes and measures that improve efficiency: how much did the standards raise costs of energy and how much was the cost per unit of energy saved? Moreover, where they do carry out the studies some elements of the cost of making the reduction are ignored (such as costs of changing practices, procedures etc.).

The literature also shows that the largest effects of these instruments could be obtained in developing countries, where the stock of buildings is still growing. Iwaro and Mwasha (2010) survey 60 counties from Africa, Latin America and Middle East, and suggest that despite the growth in the number of standards during last years and some improvement in energy efficiency, most of them are far from the minimum level required in industrialized countries.

Finally recent reviews of the literature on standards shows that instruments such as energy efficiency standards (e.g. Energy Performance of Buildings Directive) have been one of the main drivers of innovation (Noailly, 2012). The literature also suggests that public R&D financing plays an important role in innovation as compensation for underinvestment in the private sector (Popp, 2006).

4.2. Fiscal Instruments

Energy taxes also have a long history that has raised a multitude of *ex post* empirical evaluations from the different policy initiatives introduced by governments all around the world. The transport sector is one of the preferred targets for tax policies (there are not many precedents of energy efficiency taxation in residential sector), in particular road transport, which represents nearly 70% of the CO_2 emissions from transport. The most common taxes used in this sector are fuel taxes, taxes on vehicle purchase and annual property taxes (the last two are usually based on different attributes of the vehicle). The final goal of these policies can be revenue raising, environmental or related to energy dependence (see Gago et al., 2013b). In the European Union purchases and property taxes have been shifting from taxing engine power or size to CO_2 emissions or fuel consumption. For an overview of the existing research in this area see Ryan et al. (2009). The effect of such taxes on energy demand is well established: witness the difference in car engine size and fuel consumption between North America where fuel taxes are low and Europe where they are much higher.

The cost effectiveness of tax schemes is less well researched. We know that there are welfare losses associated with taxes but how much are we paying in terms of such losses per unit increase in energy efficiency? A study by Markandya et al. (2009) looked at this question for a policy of increase in energy taxes and found in general that the cost per ton of CO_2 reduced in selected European countries was negative in the case of energy savings from refrigerators, water heaters and light bulbs. This cost included the traditional welfare cost to consumers as well as administrative costs of implementing the tax and welfare gains to producers of more expensive equipment. Thus a tax option at least in this context looks like an attractive option for increasing energy efficiency.

The same cannot be said so easily for measures in the form of subsidies. A number of studies have looked at the impacts of subsidies in various forms of rebates and subsidized loans (Train and Atherton, 1995; Revelt and Train,1998; Datta and Gulati, 2001; Markandya et al., 2009; Nadel, 2012, Suerkemper et al., 2012, Galarraga et al., 2013, Alberini et al., 2013)[4]. Most find that the subsidy does have a positive effect on the choice of more efficient appliances. In general, rebates at purchase are more effective per euro compared to subsidised loans. Tax credits are also relatively cost effective when measured in terms of the cost per ton of CO_2 removed. Two main drawbacks related with rebates are free-ridership and rebound effects. Grösche and Vance, (2009) identity this as a necessary condition for free-ridership, and find that roughly 50% of the western households in Germany also present a WTP higher than the observed cost for certain retrofit options. Indeed, using a choice experiment in Switzerland, Banfi et al., (2008) find that willingness to pay (WTP) for energy-saving measures generally exceed the cost of such measures. Secondly, Galarraga et al. (2013), find a significant rebound effect from the rebates on purchase in that energy bills rise for those who purchase the more efficient appliances. On the other hand an increase in tax has no such rebound effect and a smaller welfare cost. Alberini et al. (2013) find no reduction in electricity consumption for those who purchase a heat pump under a rebate but a 16% reduction among those who made the

[4] The range of subsidies is very wide and the instrument takes many forms. It is very common for example to use renovation or 'scrappage' plans, which consists of subsidizing the substitution of inefficient products by new ones with a certain energy efficiency requirements, especially during economic recessions. However, the principal goal of these plans is frequently to activate the market and not really environmental protection (Brand et al., 2013). Nevertheless, the use of such measures is also supported by some evidence through consumer surveys which show that the up-front investment cost is one of the main factors driving consumer decisions. This is the case with low-carbon technology vehicles in the UK (Mourato et al., 2004).

same purchase without a rebate, suggesting that the rebound effect is greater with the subsidy[5]. Finally Markandya et al. (2009) make a direct comparison between a tax incentive and a subsidy and find that the welfare cost of the subsidy is almost always higher than that of a tax and the same applies to the cost per ton of CO_2 removed.

Thus we have the situation where the more politically popular instrument (subsidies) is less cost-effective than the less popular one (taxes). Yet subsidies may be in occasions more effective than other instruments that lead to energy price increases (Hasset and Metcalf, 1995). We have already noted the arguments that taxes have negative distributional effects and, although we are inclined to the view that such effects are exaggerated, should they occur it may be necessary to introduce complementary policies that product vulnerable groups from being disproportionately affected.

Another feature of the tax/subsidy instruments for energy efficiency is the wide range of values at which they are applied across different sectors. If the aim is, for example, to reduce CO_2 emissions the tax or subsidy should be such that the implied benefit to the emitter of a ton of CO_2 is the same irrespective of which sector is comes from. In practice this is far from the case. Table 2 shows the implicit cost of abatement of CO_2 for different fuels for a selection of European countries.

Table 2: Implicit Abatement Costs for Different Fuels in the Electricity Sector (€/Ton)

	Hydro	Wind	Biomass	Biogas	PV	Geo-thermal	Waste
Czech Republic	83.2	21.1	59.3	166.2	790.4	::	::
France	133.2	385.2	536.8	420.7	5381.0	::	::
Germany	67.4	77.6	228.6	::	733.8	294.5	::
Italy	149.9	142.1	224.8	::	759.5	153.8	::
Netherlands	224.9	185.4	171.0	::	890.2	::	111.3
Poland	::	::	::	::	::	::	::
Spain	124.8	129.2	219.8	::	1134.3	::	84.5
United Kingdom	131.0	145.4	129.5	127.6	416.7	::	::

Source: BC3: CECILIA Project.

As Table 2 shows this is far from the case. The implied abatement cost per ton of CO_2 is very high for PV and relatively low for wind and hydro. There is thus considerable scope of increasing the efficiency of the tax structure so that cost per unit reduction in CO_2 or increase in energy efficiency is the same across different sectors.

[5] Research on the rebound effect arising from these subsidies is problematic. The difficulty of estimating indirect rebound effects (see the discussion above) has constrained the development of research in this area (see Davis et al., 2012).

More limited information is available on obligation systems, one of the more innovative policy instruments to promote energy efficiency. Despite the fact that they are attracting a growing interest among different governments, probably due to their social acceptability, they still have a short lifespan, which strongly limits the empirical analysis. In the case of obligation or white certificates systems, their recent introduction does not allow an *ex post* evaluation. Researchers have mainly tended to develop summaries and reviews of the different initiatives carried out in Europe, comparing the characteristics of each system. Mundaca and Neij (2009) gather information from different sources such as official documents, or interviews with experts or regulators, to carry out a multi-criteria evaluation of the experiences in UK and Italy. The analysis indicates that both systems have achieved a high degree of success because the programs were not very ambitious. One additional problem faced by such analyses is the difficulty to identify the energy savings associated with business-as-usual.

However, given the interest the European Union has shown regarding the possibility to introduce an obligation system, there have been some simulation exercises to estimate the effects of such initiative (e.g. Farinelli et al., 2005; Mundaca 2008). The main results of such simulations point to the existence of an important potential to reduce energy consumption from residential and commercial sectors in the EU-15, but also inform about the necessity to carefully analyze how those savings will be distributed among Member States.

4.3. Information Systems

Regarding energy performance certificates or labeling systems, the main limitation is the lack of complete databases containing information on household energy consumption and availability of electric stock. Since energy performance certificates have been mainly used at the residential level to distinguish buildings, appliances or vehicles, the major challenge for governments is the development of multi-year surveys that collect information about household energy consumption and energy efficiency products. Such databases would allow us to identify changes in energy consumption due to the introduction of this policy measure. Due to such limitation, analysts have focused on estimating the willingness to pay of consumers for energy efficient products. It is expected that if consumers are willing to pay more for certified products this is because they are correctly recognizing and including the information provided in such certificates among their preferences and, hence, certificates are successfully providing information.

Most of these studies focus on buildings and appliances and, depending on the source of data used for such purpose, the literature can be classified in two groups: on the one hand studies that apply the hedonic price method with real data and, on the other hand, studies that generate data using experimental techniques. The former have been applied for commercial buildings, mainly in the US and some Asian countries (Eichholtz et al., 2010; Fuerst and McAllister, 2011a; Brounen and Kok, 2011; Deng et al., 2012; Fuerst and McAllister, 2011b; Yoshira and Sugiura, 2011) and for appliances and vehicles in Spain (Gallarraga et al., 2011; Gallarraga et al., 2013); while the later have been used for the residential sector, especially in Europe (Achtnicht, 2011; Alberini et al., 2013; Banfi et al., 2008; Kwak et al., 2010; Sammer and Wüstenhagen, 2006). The findings of the majority of these studies find a significant positive willingness to pay for such products.

Finally, as it was mentioned in section 3, there are some other informational mechanisms to reduce energy consumption in residential sector that are also gaining attention for policymakers and empirical researchers, particularly billing information and smart meters. Since individual behavior is a main determinant for the effectiveness of these instruments, and real data is missing due to a lack of experiences, experimental techniques have been the most common approach to evaluate them. In particular, there are several field experiments that estimate changes in energy consumption due to the introduction of smart meters (Jessoe and Rapson, 2013; Gans et al., 2013; Thorsnes et al., 2012; Doostizadeh and Ghasemi, 2012) or billing information (Schultz et al., 2007; Nolan et al., 2008; Allcott, 2011). It is worth mentioning a large randomized natural field experiment carried out by Allcott (2011) among 600,000 households across the US which found an average 2% reduction of energy consumption by households whose electricity bill included information about the consumption of their neighbors. Similar effects were found by Houde et al., (2013) for California, with an average 5.5% decrease in electricity consumption by households who received detailed information through an innovative web interface developed by Google.

4.4. Interactions among Policies

The general impression one gets from the survey of the literature is that governments have been operating under a significant knowledge gap in this area and have been approving many different energy policies with the objective of reducing the energy efficiency gap but without a clear idea of how well they will work. This process has created a situation where many policies simultaneously co-exist in time. For illustrative purposes, Table 3 shows the current number of energy efficiency policies in France, classified by type of measure and sector.

This creates of course a situation where there are many interactions among policies. Sometimes those interactions can be negative and lead to inefficient and unexpected results, while synergies might remain unexploited. Following Tinbergen's (1952) Rule, to reach efficient solutions the number of targets should be equal to the number of policies. However, the use of more than one policy in a given area is justified in the case of market failures and equity issues, as a second best approximation (Bennear and Stavins, 2007; OECD, 2007; Sorrel, 2003).

Yet, clearly the entire current mix cannot be justified on these grounds. There is a lack of literature analyzing the interaction among general energy policies, in a context of complex regulatory saturation. As it was shown in the preceding section, the academic literature has mainly focused on estimating the results from individual national policies or simulations of certain policy proposes. But little is known about the magnitude of the multiple interactions existing among energy policies. Given their real-world relevance, authors have focused on the interactions between the EU-ETS and renewable energy policies (see, for instance, Sorrell, 2003). However, interactions between energy efficiency and other renewable/environmental policy instruments have received less attention. Some authors point out important interactions when green certificates and white certificates or obligation systems are introduced (Del Rio, 2010; Ryan et al., 2011; Oikonomou et al., 2008). Other interactions include:

a. Increased risk for agents when reacting to one instrument or deciding on actions in the energy area to know how the other instruments will unfold over time.
b. Rebound effects from subsidies increasing energy demand across related sectors when instruments have been introduced to specifically reduce demand in those sectors.
c. The very low price in the ETS resulting in a major reduction in emissions allowances in the future so as to raise the price but, at the same time, with little knowledge on how the subsidy schemes will change in the future and what innovations they will generate.

Table 2. Current number of energy efficiency policies in France

Country/measures	Household	Tertiary	Industry	Transport	Cross-cutting
Financial	10	4	3	2	-
Fiscal/tariffs	4	-	-	4	-
Information/education/training	5	3	2	4	-
Legislative/info	6	3	-	1	-
Legislative/normative	7	8	1	4	-
Unknown	7	1	1	3	-
Co-operative	2	2	3	4	-
Infrastructure	-	-	-	4	-
Social planning organization	-	-	-	2	-
Other	-	-	-	-	20

Source: Project ODYSSEE-MURE

5. Conclusions

Improving energy efficiency has become one of the preferred options for governments to reduce energy consumption and its associated costs and emissions. In this paper we look at the different polices and present the general context for public intervention in this area. Experts have identified a large number of measures that make promote energy efficiency. Unfortunately many of them are not cost effective. This is a fundamental requirement for energy efficiency investment from an economic perspective. However, the calculation of such cost effectiveness is not easy: it is not simply a case of looking at private costs and comparing them to the reductions achieved. There are significant externalities to take into account and there also macroeconomic effects. For instance, at the aggregate level, improving the level of national energy efficiency has positive effects on macroeconomic issues such as energy dependence, climate change, health, national competitiveness and fuel poverty. And this has direct repercussions at the individual level: households can reduce the cost of electricity and gas bills, and improve their health and comfort, while companies can increase their competitiveness and their productivity. Finally, the market for energy efficiency could contribute to the economy through job and firms creation.

Despite all these benefits, the market for energy efficiency presents several market failures and other market barriers that make the level of private investment suboptimal. Incomplete information, the principal-agent problem, the difficultness to access to capital, bounded rationality or risk aversion, are among the important hurdles. This situation not only justifies public intervention, but also determines the context for such intervention. Due to the multitude of market imperfections, no single policy is sufficient to promote energy efficiency alone. As a result, during the last decades governments have been implementing codes and standards to guarantee a minimum level of energy performance, economic instruments to give incentives for reducing energy consumption, and more recently new market-based instruments such as permits, obligations or energy performance certificates. The current situation is thus characterized by a simultaneous co-existence of a multitude of policies, which can be confusing and inefficient due to their negative interactions.

The academic literature has focused on estimating the individual results of each public initiative. Different approaches have been adopted for such evaluation; however little is known about the potential interactions among policies. In a multi-policy context there is a large probability for negative interactions and unexploited synergies among policies. This should be the area for future academic work, and the corresponding findings should be used to design and implement policy packages (see e.g. Gago et al., 2013a).

Given the range of instruments that exist it is not easy to select the optimal combination. There is a need to carry out a comprehensive review of all instruments in an economy-wide framework so interactions can be specifically allowed. The aim for a transition to reform policies in this sector should be based on:

- Eliminating those policies that do not work cost effectively in the sector and for the purposes for which they were intended.
- Setting the levels of the others so that they take account of cross and interaction effects.
- Brining in additional instruments that address problems created by the ones that have been introduced (e.g. distributional issues arising from energy taxes).

This transition cannot be made overnight but it is time to make a start and hopefully over the next decade we will have a more effective policy framework to promote energy efficiency. A key role in this will have to be played by the economic analysis of the cost effectiveness of different instruments within an agent-based framework.

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