Energy Economics 52 (2015) S1–S4

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

Frontiers in the economics of energy efficiency

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ARTICLE INFO

Keywords:
Demand
Policy
Rebound
Renewable
Environment

ABSTRACT

Energy efficiency has become an essential instrument to obtain effective greenhouse gas mitigation and reduced energy dependence. This introductory article contextualizes the contributions of the supplemental issue by showing the new setting for energy efficiency economics and policy; discussing the role of price instruments to promote energy savings; presenting new approaches for energy efficiency policies; and placing energy efficiency within a wider energy and environmental framework.

1. A new context for energy efficiency economics

Pursuing energy efficiency is becoming a priority for governments, firms and households across the world. Although the relevance of energy efficiency to reduce pollution and energy dependence has been widely acknowledged at least from the 1970s, the issue is gaining momentum. Several reasons are behind this, but probably the growing concerns on climate change phenomena and the related emphasis in greenhouse gas mitigation are playing a major role. Indeed, recent studies and reports that deal with the mitigation alternatives and paths that are compatible with the 2 °C climate policy objective underline the relevance of energy efficiency (e.g. IEA, 2015; IPCC, 2014). Yet other novel arguments, such as the competitiveness and distributional benefits of higher levels of energy efficiency for firms and households, are also increasingly present in the debate. It is worth noting too the growing interest of emerging and developing countries in improving their performance in energy efficiency terms, with an emphasis on the significant climate, local pollution and energy security gains that could be attained this way in countries that might be more reluctant to the implementation of explicit environmental policies.

Such socio-economic and political interest in energy efficiency is bringing about a considerable expansion in the scope and depth of academic enquiries within economics. It is true that the 1970s saw a remarkable interest in the economics of energy efficiency and that by the turn of the century many theoretical and empirical insights had provided a sound basis for the discussion of the so-called energy efficiency 'paradoxes' and for the design and implementation of corrective policies. It was then clear, based on a considerable economic literature, that standard regulatory approaches, proper energy pricing, overcoming 'market barriers', and proper information could all contribute to improve energy efficiency indicators. However, much effort has been devoted in the last few years to try to explain the persistence of barriers to energy efficiency and to assess the ambitious regulatory tools put in place in the European Union, the U.S. and other developed countries. Moreover, innovative policy alternatives that explicitly consider free-riding and behavioral barriers, a remarkable progress in measurement and information technologies, and the strong irruption of quasi-experimental and field experimental approaches in the area, clearly define a new setting for energy efficiency economics and policy.

This supplemental issue therefore responds to the intense interest of academic economists in energy efficiency, with a clear bias towards energy efficiency policies, although it also includes a few papers less directly linked to the topic. The articles are authored by participants in the Sixth Atlantic Workshop on Energy and Environmental Economics, held in A Toxa (Galicia, Spain) in June 2014 under the title of this introduction 'Frontiers in the Economics of Energy Efficiency'. The Atlantic workshop, organized by the research center Economics for Energy with the collaboration of ZEW in its sixth edition, had already provided two supplemental issues of Energy Economics in 2011 and 2013. As guest editors we are thankful to Richard Tol (editor-in-chief of Energy Economics) for his continuous support, and also to the anonymous reviewers that made possible the quick and timely publication of the issue.

Besides explaining the reasons behind the supplemental journal issue, this introductory article intends to summarize and categorize the different contributions. As advanced before, most articles in this issue deal with the design and assessment of energy efficiency policies and thus the next three sections are devoted to price-based approaches, new policy approximations to improve energy efficiency and to the questions raised by the so-called rebound effect. The paper ends with a wider look at energy and environmental matters that can influence and/or be influenced by energy efficiency developments.

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http://dx.doi.org/10.1016/j.eneco.2015.11.012
0140-9883/

But before proceeding with the next sections, it is particularly useful to shed light on the very concept of energy efficiency. Although energy intensity is often used as a proxy, particularly in energy policy analysis, there is no consensus on how energy efficiency must be defined and measured at the macro level. The article by Filippini and Hunt (2015), based on one of the keynotes of the workshop, precisely answers these two questions by reviewing the several attempts to define energy efficiency and by paying a special attention to both the econometric methods that are fit for a proper measurement and to the specific results from recent empirical work.

As hinted before, the EU has been emphasizing the role of energy efficiency in its energy and climate strategies and objectives since the late 1990s and thus provides a good laboratory for inferring conclusions that may be useful for the policymaking and academic communities. In this context, Löschel et al. (2015) are interested in showing the evolution of energy efficiency based on the above-mentioned concept of energy intensity. The authors analyze the decline in energy intensity in the EU-27 countries between 1995 and 2009, trying to identify the factors that explain changes in energy intensity of countries. More specifically, they focus on structural changes towards less energy-intensive sectors and changes in sectoral energy intensity as the potential channels that may explain this evolution. The article finds that both drivers were similarly important from 1995 to 2003 and that technological improvements in sectoral energy efficiency were the predominant drivers afterwards. In any case, there is significant heterogeneity between the 27 countries.

2. Prices and energy efficiency

Market instruments that directly impact energy prices are a preferred energy-efficiency policy because of their simplicity, cost-efficiency and easy implementation, even though their effectiveness in this area may be reduced when price elasticities of energy demand are very low. Price instruments generate incentives to reduce energy consumption by either using taxes that penalize energy consumption or subsidies or tax deductions that encourage energy savings (see, for example, Markandya et al., 2015).

In many developed countries energy taxes have been instrumental in controlling energy consumption and, by doing so, they have also limited carbon dioxide (CO_2) emissions and reduced energy dependence through energy efficiency improvements. Besides achieving environmental, energy and other economic objectives, these instruments have the advantage of being capable of generating public revenues. This is the case of several developed, mainly EU, countries which implemented environmental tax reforms since the early 1990s, raising taxes on energy sources and using the extra revenue to reduce personal income taxes or/and social security contributions (see Gago et al., 2014).

This is the setting for De Miguel et al. (2015), who analyze a green tax reform aiming to improve the Spanish social security system and that could generate significant reductions in energy demand and contribute to a better environment. Yet the authors also highlight the difficulties of implementing such a policy despite its potentially beneficial effects, mostly due to the different ways in which the policy affects several age groups. This is something that needs to be taken into account when considering the design and implementation of such a package, clearly beneficial from economic, energy and environmental point of views, but potentially subject to socio-political barriers that should be targeted.

Another set of price instruments seeks to generate energy savings through subsidies in the form of rebates or loans that might have a positive effect, for example, on the choice of more efficient appliances. This can be done by subsidizing the replacement of inefficient products for new ones with certain energy efficiency requirements, as actually discussed by several papers in previous supplemental issues related to the Atlantic workshop (see, for example, Galarraga et al., 2013). Yet there are several negative aspects of subsidies such as the revenue (fiscal) costs of providing the subsidy, free riding, or the possible presence of the so-called rebound effect. The latter happens when the subsidy reduces the price and can lead to an increase in energy consumption, and will be analyzed in Section 4.

In this issue Nauleau et al. (2015) discuss, from a theoretical point of view, how to design a program of subsidies to promote energy efficiency improvements in a market under several market failures. The authors explain that the presence of energy use externalities and price-quality discrimination causes low energy efficiency levels. As a major result, the paper indicates that differentiated subsidies can generate the social optimum.

An extensive empirical literature has analyzed the effects of introducing different subsidies in view of the free-riding phenomena (see e.g. Linares and Labandeira, 2010). Within this journal issue and with the above-mentioned objectives Alberini and Bigano (2015) analyze the role of both monetary and non-monetary incentives in encouraging households to replace their heating systems with a more energy efficient system. Using a survey of homeowners elaborated by the own authors, the analysis focuses on Italian households. As a major contribution, the authors fit an energy-efficiency renovations curve that predicts the share of population willing to undertake these improvements for any given incentive level.

As indicated in the introduction, competitiveness and distributional considerations are occupying an increasing space in the energy efficiency debate. Indeed, trade flows across countries can also have significant implications on energy and the environment in an increasingly globalized world. There is actually an extensive literature that deals with the link between climate policy and trade from both a theoretical and empirical points of view (see, for example, Copeland and Taylor, 2003). Among the factors that may influence trade flows, the empirical literature has generally paid less attention to energy costs differences among countries despite its potential importance. Differences in energy costs are a very important factor as producers of a country can respond to higher energy prices producing less of the energy-intensive goods at home or even partially relocating their production to countries with lower energy prices. From the environmental point of view this is important as the reduction of emissions in a country might simply be offset by increases in other regions. Sato and Dechezleprêtre (2015) contribute to the literature that empirically analyzes the relationship between energy prices and trade, estimating a gravity model using a panel that covers tens of countries and sectors for the period 1996–2011. They find a significant but very limited impact of energy price gaps on imports, although this is larger for energy-intensive sectors.

3. New approaches for energy efficiency policies

As stated in the introduction, in the last few years there have been important efforts by academics and policymakers to tackle the pervasive barriers to energy efficiency improvements. The supplemental issue pays a particular attention to this topic by providing an updated survey on new developments in energy efficiency policies and by presenting one of the first empirical assessments of such innovative approaches.

Ramos et al. (2015) explore a relatively new field in energy efficiency policies: instruments that provide information to consumers as a way to solve the informational failures present in the residential sector. The article reviews the available evidence on the relevance of informational and behavioral failures related to residential energy savings and then analyzes the performance of three instruments that try to address informational failures: energy certificates and labels, provision of feedback to consumers, and energy audits. The paper shows that energy certificates and labels and the provision of feedback show better results than energy audits. The authors conclude that, although these instruments show some promise, several shortcomings should be overcome if they are to solve the energy efficiency paradox and make energy efficiency happen significantly in the residential sector.

Alberini and Towe (2015) examine the effects of two residential energy saving programs on energy consumption that were considered by the preceding paper and in Section 2 of this article: a home energy audit program and a rebate on the purchase of high-efficiency heat pumps. Using a panel data of monthly electricity usage from participating and non-participating households in Maryland, U.S., the paper estimates a coarse exact matching model. The authors report limited responses, 3% to 5% reductions in electricity usage, from the application of the contemplated policies.

In sum, a few papers of the issue reports new interesting developments in energy efficiency policies whose assessment, in any case, seems to indicate only moderate effectiveness of the measures. New research that explicitly deals with the assessment of such novel alternatives, providing clues on how to improve their performance, is clearly needed.

4. On the rebound effect

As indicated before, improved energy efficiency does not necessarily imply a proportional reduction in energy consumption. In fact, a reduction in the effective price of energy caused by the introduction of an improvement in energy efficiency may actually cause an increase in energy demand (direct effect) or it may indirectly cause an increase in disposable income which may in turn leads consumers to increasing their consumption of other energy goods, be it at the micro or macro level (indirect effect). Thus, the existence of a rebound effect may limit the scope of energy efficiency policies. Therefore, in order to determine the final scope of a measure to improve energy efficiency, it is necessary to assess the price and cross-price elasticities for energy and other goods and services, and also general equilibrium effects. A few articles of the supplemental issue deal with these questions.

Gillingham et al. (2015) use a dataset constructed from vehicle emissions inspection tests data from Pennsylvania, U.S., to discuss the implications of the rebound effect in response to changes in gasoline prices. To do this, the article estimates the elasticity of the use of vehicles with respect to gasoline prices as a proxy for the direct rebound effect. This approach is essential, for example, when there is interest in knowing the effects of taxes on gasoline. The authors find a relatively small direct rebound effect in the short-run, yet a considerable heterogeneity in the response when taking into account factors such as the age of the vehicle or the types of vehicles. This is a fundamental aspect in the analysis as it would imply that consumers might respond differently to a change in gasoline prices and this could introduce a significant constraint for the design of energy efficiency policies.

Despite the possible importance of indirect rebound effects, the literature has paid less attention to estimating them (see Chitnis et al., 2014). In general, analyses have focused more on studying the increase in consumption due to lower energy prices instead of dealing with the increase in the consumption of other complementary goods due to increased disposable income. In this issue Chitnis and Sorrell (2015) discuss several methods for estimating the direct and indirect (income) rebound effect with an application to various energy efficiency programs implemented on UK households. Using cross-price elasticities rather than expenditure elasticities, the paper is able to identify both the direct and income rebound effect because it can capture the contribution of both the income effect and the substitution effect of improvements in energy efficiency. The results confirm that not taking into account income rebound effects has resulted in an underestimation of total rebound effects.

5. A wider look

Long-term decarbonisation pathways are characterized by the crucial role of energy efficiency improvements. However, energy sustainability involves not only reducing energy demand, the main focus of this issue so far, but also a rapid decarbonisation of energy supply, essentially the rapid development of renewable energy sources. Thus, governments should implement a dual strategy: on the one hand contain the consumption of fossil resources and on the other diversify energy sources and promote the development of clean alternatives. Moreover, both options interact and it is important to gain a deeper understanding also on the economics of renewable energy.

There is an extensive literature that analyzes the potential role of different sources of renewable energy for an effective reduction in greenhouse gas emissions. Solar energy is particularly mentioned, despite its surprising small role given its enormous potential. In this issue Schmalensee (2015) assesses the future contribution of solar energy to electricity production, showing that several barriers, but mostly its current high costs, limit the potential scale-up of this technology. Current deployment support policies, which are highly inefficient, are unlikely to solve the barriers to scaling up solar energy. The paper indicates that, to overcome high costs of renewable energy, ambitious R&D efforts aimed at fundamental advances need to be undertaken. These R&D initiatives will also provide technology spillovers to the rest of the world.

As just indicated, it is essential to take into account the associated costs in the development of renewable energies. In this respect, the so-called learning curves are a useful instrument because they allow forecasting the future costs of renewable technologies. Another paper of the issue, Witajewski-Baltvilks et al. (2015), starts by discussing the problems with the use of learning curves. The paper subsequently enumerates the necessary assumptions that allow reliable predictions on the basis of available empirical estimates of the learning curve. Reverse causality is identified as the main problem for the analysis and econometric solutions are proposed that can deal with this endogeneity issue.

Summing up, this supplemental issue provides new insights on the definition and measurement of energy efficiency improvements, ex-post developments in energy intensity and its drivers, the role of taxes and subsidies to incentivize energy savings, the scope of potential rebound effects as well as linkages to the development of renewable energy technologies. We believe that the issue is particularly timely, published just ahead of the Paris COP of December 2015. More than 140 states covering more than 90% of global greenhouse gas emissions have submitted the so-called Intended Nationally Determined Contributions (INDCs) at the moment of writing, which describe their climate policy measures under a global agreement to be negotiated in Paris. Energy efficiency plays a major role in most of these plans: in fact, around 85% of INDCs highlight energy efficiency as a priority area for their efforts to fight climate change (UNFCCC, 2015).

The future in-depth assessment of the INDCs will have to analyze the scope, potential and cost associated with the currently vague energy efficiency strategies. Besides ex-ante studies, the ex-post assessment of energy efficiency policies is crucial for this analysis. What can efficiency standards, energy taxes and subsidies and information instruments achieve and what are the obstacles to be taken into account to close the so-called energy efficiency gap, conform essential questions. As are those related to the broader economic costs associated with these policies; or to the role of innovation and R&D and how is this linked to energy efficiency policies. As the energy sector is increasingly characterized by 'smart' energy solutions for low-carbon generation, efficient distribution and optimized consumption, more data will be increasingly available to learn about energy demand under different environments. Quasi-experimental studies and field experimental studies will be thus useful to evaluate causal effects of energy efficiency measures. The daunting task is the generalization of these insights, the comparability between countries and sectors and the integration of more micro-based and behavioral findings in more macro-oriented assessments as needed for the post-Paris process. Hopefully this supplemental issue provides a small step in that direction.

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