Energy Policy 37 (2009) 4787–4796

Contents lists available at ScienceDirect

Energy Policy

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

Energy saving and energy efficiency concepts for policy making

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ARTICLE INFO

Article history:
Received 9 March 2009
Accepted 9 June 2009
Available online 5 July 2009

Keywords:
Energy saving
Energy efficiency
Energy policy

ABSTRACT

Departing from the concept of rational use of energy, the paper outlines the microeconomics of end-use energy saving as a result of frugality or efficiency measures. Frugality refers to the behaviour that is aimed at energy conservation, and with efficiency we refer to the technical ratio between energy input and output services that can be modified with technical improvements (e.g. technology substitution). Changing behaviour from one side and technology from the other are key issues for public energy policy. In this paper, we attempt to identify the effects of parameters that determine energy saving behaviour with the use of the microeconomic theory. The role of these parameters is crucial and can determine the outcome of energy efficiency policies; therefore policymakers should properly address them when designing policies.

1. Introduction

Energy efficiency is a term widely used, often with different meanings in public policy making. A clear distinction between energy efficiency and energy conservation is that the former refers to adoption of a specific technology that reduces overall energy consumption without changing the relevant behaviour, while the latter implies merely a change in consumers' behaviour. In psychology, this has been labelled as efficiency and curtailment behaviour (Gardner and Stern, 2002). Many aspects and influencing parameters on the total outcome of an energy system, from the demand and the supply side, have to be taken into consideration, hence energy efficiency improvement estimation demands analytical processes. In this respect, economic literature has frequently taken as given the microeconomic parameters affecting energy efficiency and energy conservation (Howarth and Andersson, 1993; Sanstad and Howarth, 1994; IEA, 1997; Mintel International Group Ltd., 1997; Howarth et al., 2000; Clinch et al., 2000; Poortinga et al., 2003; Sorrell, 2004; Bor, 2008). Nevertheless, actual practice demonstrates that economic and technological assumptions (of perfect information and absence of transaction costs) on these parameters do not necessarily hold in the market, which shifts energy efficiency patterns (Jaffe and Stavins, 1994). Policymakers often decide on specific policies and instruments on the ground of standardized assumptions of energy use and energy saving behaviour of end-users.

In many policy cases, energy efficiency improvement is set as an environmental target with strong assumptions on the rationality of end-users and their responsiveness to price signals, while such ex-ante assumptions should be verified with ex-post data, already appearing in the literature. Naturally, rationality of energy behaviour can be related to more parameters, as for instance effort, status, income, and many others. Energy efficiency policy instruments are mostly designed based on a normative perspective of market behaviour of economic actors, which are assumed to receive the market signals and act on the grounds of their own rationality. Still, the economic rationality in energy use and energy saving behaviours is an often entangled topic and depends on various parameters.

The purpose of this paper is to identify the relationships between various economic variables that determine the behaviour towards energy efficiency. More specifically, departing from the microeconomic theory, we attempt to unveil some parameters that should be taken into account by social planners, when designing policies for energy efficiency improvement.

The structure of this paper is as follows. In Section 2, we provide some basic definitions of somehow overlapping concepts of energy savings and energy efficiency. Section 3 refers to a microeconomic analysis of energy saving, rational use of energy, energy services, and the effects of time into energy savings. Furthermore, Section 4 deals solely with microeconomics of energy efficiency, incorporating concepts of rebound effects, real and shadow energy demand, the effects of time dimension in energy efficiency. Section 5 provides a discussion on energy saving and energy efficiency components as economic value reservoirs. Finally, in Section 6, we wrap up our theoretical

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doi:10.1016/j.enpol.2009.06.035

analysis and come up with some recommendations for policy making.

2. Definitions

In this section, we provide a general overview of the terms met in the literature of energy efficiency, which can often overlap and create confusion. Consumer behaviour and lifestyle choices are strongly related to the concept of the rational use of energy, the end-use (final) energy saving and the end-use energy efficiency. Energy savings and energy efficiency refer to two microeconomic situations, which deserve to be differentiated. Energy efficiency concerns the technical ratio between the quantity of primary or final energy consumed and the maximum quantity of energy services obtainable (heating, lighting, cooling, mobility, and others), whilst end-use energy saving addresses the reduction of final energy consumption, through energy efficiency improvement or behavioural change.

In many studies, the energy conservation concept refers to the reduction of energy consumption associated with a frugal lifestyle that includes a form of regulation (i.e. speed limitations, reduced domestic heating, and so on) or spontaneous changes in consumers' preferences resulting in behavioural changes. This concept often implies a more moral aspect of behaviour rather than a strictly economic one, since effort is required from the end-users side in order to engage in energy saving. An extensive literature review on the matter of 'sufficiency' can be found in Alcott (2008) and on sustainable consumption in Jackson (2007). Nevertheless, energy conservation can be enhanced via changes in the context (including regulations and energy price increases) and changes in motivations of people (including environmental concerns, and feelings of moral obligation to reduce energy consumption). An exhaustive literature survey on the matter can be found in Herring (2004) and Steg (2008). Policies in this aspect can target either investments towards energy-efficient goods (as for instance subsidies) or behavioural changes (feed-in tariffs for energy savings, see Bertoldi et al. (2009)), or both.

In this study, strictly confined to the field of end-use energy demand, the two concepts of energy savings and energy efficiency are used in a specific and distinct way. In some cases, nevertheless, the energy saving concept is also used with its general and widespread meaning such as the reduction of energy consumption. As mentioned above, in this paper, strictly energy end-uses are considered: complex efficiency implications in the upstream phases of transformation, transmission, and distribution are beyond the scope of this paper.

3. Microeconomics of energy saving

In this section, we present the basic microeconomic variables and functions of energy saving, which describe the parameters influencing positively or negatively energy saving trends. These functions are built upon energy services, energy savings, and the effect of time horizon on energy efficiency.

3.1. Energy services

In order to analyze energy savings and energy efficiency, we start from a very basic model on energy services expressed in the following function:

$$Qs = f(Qe) \tag{1}$$

where Qs is the required energy services (measured in GJ) and Qe the final consumption of energy (measured in GJ).

The function f corresponds to an overall set of technology transformation processes and to the related boundary conditions in which these processes develop in order to accomplish energy end-uses in defined environments (houses, offices, etc.). One can omit the formalization of the relationship between these processes, the conditions of the defined environments and services produced, because investigating technology transformation functions, is out of the scope of the paper that is instead focused on the combined effect of energy conservation and energy efficiency actions.

At a second step, we express the final consumption as a function of energy services (Eq. (1))

$$Qe = f^{-1}(Qs) \tag{2}$$

The same function, with the strong assumption of linearity, can be expressed as

$$Qe = \beta Qs \tag{3}$$

where β is the technical parameter expressing the conversion efficiency of technologies in which we can add a disturbance factor, thus enabling us to take human behaviour into consideration

$$Qe = \beta Qs + \upsilon \tag{4}$$

where υ is the exogenous variable related to human behaviour and to organisational processes (measured in GJ of energy used).

Eq. (4) practically implies that final energy end-use is dependent on demand for energy services but forecasting its evolution must take into account social parameters. In particular, it can be noted that the linear relationship expressed with the parameter β, between the quantity of end-use energy consumed and the quantity of services obtained, is reasonable if we consider non-linear relationships as linearized (i.e. linear approximations): the first derivative of the linear approximation is a multiple-step function where the base of each step is the linearization range that has to be defined accordingly to each technology transformation. As stated before, the in-depth investigation of the technology transformation is out of the scope of the paper, but it may indeed represent an interesting development for further research, for instance focused on a specific sector like household appliances.

In the short-term, with given domestic technologies, parameter β is exogenous. Nevertheless, as shown later, it is affected by investments in energy efficiency and endogenized in the model. Moreover, this parameter depends on the considered sector (heating, lighting, cooling, mobility, and others). Hence, a family of sectoral parameters can be imagined: $\beta_a, \beta_b, \beta_c, \beta_d, \ldots, \beta_n$.

Subsets of parameters in the same sector can be expressed as follows: $\beta_{a1}, \beta_{a2}, \beta_{a3}, \ldots, \beta_{am}$ (for example, different kinds of lamps in the lighting sector).

The exogenous term υ expresses the effect of human behaviour and the organisational practices on end-use energy. For instance, the attention paid to switch off lights left carelessly on, the regulation of heating or cooling, the personal driving style, the usage of a certain device, the habit of managing indoor air comfort conditions with outdoor air (opening doors and windows). This parameter gains significant attention by policymakers and should be always targeted by policy instruments. The values of this parameter are quite hard to quantify and they depend on the types of services (for instance, in cheaper technologies where energy saving is not very obvious, this parameter is expected much higher than in more expensive technologies). Here, we make use of a typical 'rationalist information deficit model[1]'

[1] Rational information deficit model supposes that energy savings can be promoted by informing people about the need to do so as well as ways and means to achieve that. The main assumption here is that a lack of knowledge prevents