Energy Economics 52 (2015) S53–S62

Contents lists available at ScienceDirect

Energy Economics

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

Energy efficiency subsidies with price-quality discrimination

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ARTICLE INFO

Available online 4 September 2015

JEL classification:
D42
D62
H23
Q48
Q58

Keywords:
Energy efficiency subsidies
Price-quality discrimination
Ad valorem incentive
Per-quality incentive
Energy efficiency gap
Energy-use externalities

ABSTRACT

We compare various designs of energy efficiency subsidies in a market subject to both energy-use externalities and price-quality discrimination by a monopolist. We find that differentiated subsidies can establish the social optimum. Unlike per-quality regimes, ad valorem regimes generate downstream interferences: Subsidising of the high-end good leads the monopolist to reduce the quality of the low-end good. For this reason, ad valorem differentiated rates should always decrease with energy efficiency, a result seemingly at odds with actual practice. In contrast, with per-quality differentiated subsidies, the rates can increase if the externality is large enough relative to the market share of "low" type consumers. Contrary to differentiated subsidies, what we shall call single-instrument subsidies only achieve second-best outcomes. A uniform ad valorem subsidy should have a rate higher than that needed to specifically internalise energy-use externalities. Lastly, if, as is often observed in practice, only the high-end good is to be incentivised, a per-quality regime should be preferred to an ad valorem one. An ad valorem tax on the high-end good may even be preferred to an ad valorem subsidy if the externality is small enough and low-end consumers dominate the market.

1. Introduction

Energy efficiency has become a popular theme in the policy arena. This enthusiasm is sustained by engineering studies claiming that energy efficiency is the most cost-effective way to save energy, hence internalising the multiple externalities associated with energy use.[1] Such externalities include carbon dioxide emissions at the source of the climate change problem, local pollution, risks related to nuclear safety and domestic concerns about the security of the energy supply. They encourage the implementation of various types of energy efficiency policies around the world.[2]

Within the panoply of energy efficiency policies, subsidies are probably the most widespread instrument. Energy efficiency subsidies come in a variety of forms. In the US, under the State Energy Efficient Appliance Rebate Program (SEEARP), States used Federal funds in 2009–2010 to subsidise efficient refrigerators, dishwashers and washing machines (Houde and Aldy, 2014). The rebates were on average 12–15% of sale prices. While most states offered fixed rebate amounts, Florida, Illinois, North Carolina, and Oregon offered ad valorem rebates. In China, a one-year subsidy programme for energy-efficient home appliances was implemented in 2012–2013. The programme consisted of offering cash rebates ranging from about 100 to 400 RMB Yuan (16 to 64 US dollars) per appliance (Yao et al., 2014). In France, improvements to building energy efficiency have been eligible for ad valorem tax credits since 2005 (Nauleau, 2014). The subsidies, whose rates initially increased in proportion to the gains in energy efficiency (e.g. 15% of the price of low-temperature boilers and 25% of the price of more efficient condensing boilers), are now restricted to the most efficient options. Meanwhile, since 2014, all energy efficient options have been eligible for a uniform value-added tax reduction.

In parallel to the importance of subsidies, another regularly-observed characteristic of energy efficiency policies is the high concentration of the markets in which they are applied. In the US, Fischer (2005) documents high concentration levels in appliance manufacturing, as measured by Herfindahl–Hirschman indexes (HHI) and the market shares of the top four firms, which systematically exceed 50%. In France, HHI indexes are also substantially higher in the appliance and energy retrofit industries than in other industries (Carbonnier, 2008). The French Anti-trust authority has pointed to high levels of concentration in the heating, air conditioning and hot water industries, both at the manufacturing and retail levels, raising suspicion of collusive practices (Conseil de la concurrence, 2006).[3]

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[1] For instance McKinsey & Co. (2009) to quote only that with the greatest impact.

[2] For the European Union alone, 550 energy efficiency policies are referenced in the MURE database (http://www.measures-odyssee-mure.eu/).

[3] The five largest firms have a 59% market share in floor-standing boilers, the three largest firms have an 80% market share in wall-mounted boilers and the four largest firms have a 90% market share in electric heating systems.

http://dx.doi.org/10.1016/j.eneco.2015.08.024
0140-9883/

Imperfect competition as described above is conducive to price-quality discrimination. The problem, first studied by Mussa and Rosen (1978) for a monopoly and revisited by Cremer and Thisse (1994) for an oligopoly, can be explained as follows. A dominant firm faced with consumers having heterogeneous tastes for quality can choose to restrict the provision of quality at the bottom end of the product range while at the same time increasing the price of high-end products. As shown by Fischer (2005), this general economic problem can provide a supply-side explanation as to why energy efficiency levels are too low in the economy, a phenomenon known as the energy efficiency gap (Jaffe and Stavins, 1994).[4] More recently, Houde (2013) and Spurlock (2013) in the US and Cohen et al. (2015) in the UK found empirical evidence that appliance industries do respond to economic and regulatory signals in a manner that is consistent with price-quality discrimination.

Despite the practical relevance of the issue, little is known about the properties of energy efficiency subsidies in a context of imperfect competition.[5] Most of the discussions about the interaction between environmental policy and price-quality discrimination have focused on quality standards, pollution charges, and combinations thereof (Fischer, 2005, 2010; Plourde and Bardis, 1999). While some authors have considered tax/subsidy incentives (Bansal, 2008; Lombardini-Riipinen, 2005), attention has remained confined to single ad valorem instruments. As illustrated above, energy efficiency subsidies take a wider variety of forms in practice, with at least two unexplored consequences. First, according to Tinbergen's rule (Tinbergen, 1952), jointly addressing energy-use externalities and imperfect competition requires two instruments. Therefore, what we shall call single-instrument subsidies can only generate second-best outcomes unless they are combined with pollution charges, a much less common instrument. In contrast, differentiated subsidies, while overlooked in the literature, offer more flexibility to address both market failures.[6] Second, ad valorem subsidies have not yet been compared to specific subsidies related to the quality of the good. Such a comparison could reveal interesting effects, as suggested by the taxation literature (Keen, 1998).

Against this background, we examine the following questions: What are the normative and positive aspects of energy efficiency subsidies in a market subject to both energy-use externalities and price-quality discrimination? How do differentiated subsidy rates compare to uniform rates? How do ad valorem rates compare to per-quality rates? We provide some answers using Fischer (2005)'s model featuring a multiproduct monopolist and two consumer types with fixed market shares. We extend the model by explicitly taking into account energy-use externalities and accommodating energy efficiency subsidies.

We find that in an economy subject to both energy-use externalities and price-quality discrimination, differentiated subsidies can generate the first-best solution. Unlike per-quality regimes, ad valorem regimes generate downstream interferences: subsidising of the high-end good leads the monopolist to cut the quality of the low-end good. For this reason, ad valorem differentiated rates should always decrease with energy efficiency, a result seemingly at odds with actual practice. In contrast, with per-quality differentiated subsidies, the rates can increase if the externality is large enough relative to the market share of "low" type consumers. Contrary to differentiated subsidies, single-instrument subsidies only achieve second-best outcomes. A uniform ad valorem subsidy should have a rate higher than that needed to specifically internalise energy-use externalities. Lastly, if, as is often observed in practice, only the high-end good is to be incentivised, a per-quality regime is to be preferred to an ad valorem one. An ad valorem tax on the high-end good may even be preferred to an ad valorem subsidy if the externality is small enough and low-end consumers dominate the market. In the Appendices, we use the model to provide new results on energy taxes and minimum energy efficiency standards. We find that a second-best energy tax should be set above the marginal external cost. A second-best minimum quality standard may be set at the high-end of the product range if consumers are not too dissimilar, otherwise it should only target the low-end good.

The paper is organized as follows. Section 2 introduces the model and the market environments considered. Section 3 examines first-best, differentiated subsidies. Section 4 examines second-best, single-instrument subsidies. The results are discussed in Section 5. Section 6 concludes.

2. Model

Model notations are outlined in Table 1, equilibrium notations are outlined in Table 2 and illustrative equilibrium outcomes are summarized in Fig. 1.

2.1. Consumer demand for energy efficiency

We build on Fischer (2005)'s model and extend it to account for energy-use externalities and energy efficiency subsidies. Consumers purchase goods which, combined with energy, provide energy services such as light and heat. The energy-related goods considered can be appliances, light bulbs, heating systems, improvements to building envelopes (wall insulation, double glazing), vehicles, etc. They are characterized by their energy intensity $\phi_j > 0$, bounded from above by Φ, the energy intensity that would be offered if energy were costless. Energy intensity is the energy input per unit of energy service, hence the inverse of energy efficiency.

Energy efficiency is the only attribute of quality in the model. That is, quality is negatively correlated with energy intensity. We ignore ancillary attributes of the goods, such as capacity of appliances, aesthetics for light bulbs or safety for cars. This assumption is relevant to most choices within a capacity segment, e.g. a standard boiler versus a more efficient one of the same size, or a standard car versus a hybrid car with similar characteristics. It is less relevant to choices between capacity segments, e.g. a large boiler or car versus a smaller option with similar energy requirements per unit of capacity.[7]

We consider two levels of energy efficiency, high (h) and low (l), with corresponding energy intensities $0 < \phi_h < \phi_l < \Phi$. For consumers i, the net surplus of purchasing and using good j is

$$CS_{ij} \equiv \beta_i \left(v - g\,\phi_j \right) - p_j \tag{1}$$

$v > 0$ is the annual gross utility of the energy service. It is produced with a combination of energy, purchased at a constant price $g > 0$, and the durable good j, purchased at price $p_j > 0$.

We assume heterogeneity across the population in the valuation of energy services. This is reflected by parameter β_i, the cumulative discount factor for the net utility flow over the lifetime of the good.

[4] Supply-side explanations for the energy efficiency gap have been little studied. The existing literature on the topic tends to focus more on demand-side explanations. For comprehensive reviews, see Sorrell (2004), Gillingham et al. (2009) and Allcott and Greenstone (2012).

[5] The existing literature on energy efficiency subsidies is mostly empirical and concerned with estimating the effectiveness of, and inframarginal participation in, subsidy programmes (Boomhower and Davis, 2014; Grösche and Vance, 2009; Hassett and Metcalf, 1995; Houde and Aldy, 2014; Nauleau, 2014).

[6] Energy efficiency subsidies can be used to address either market failure in isolation. Subsidies are a conceptually valid tool to address output contraction due to market power. Yet such an intervention increases the profits of dominant firms and thus faces political hurdles. Moreover, it is only a substitute for anti-trust regulation. Subsidies can also directly address energy-use externalities. However, they may generate a rebound effect, thus saving energy less cost-effectively than taxation of externalities (Giraudet and Quirion, 2008). Note that subsidies can also be used to internalise technology spillovers, a market failure not considered in the model but discussed in Section 5.

[7] Plourde and Bardis (1999) study the opposite model in which quality is positively correlated with energy intensity, assuming that the safety attribute associated with larger cars is the main driver of choice. Unsurprisingly, they find opposite results to those of Fischer (2005).