RESOLVING MODELLING CHALLENGES RELATED TO SHIFTS IN THE DEMAND CURVE FOR ELECTRICITY

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Overview

EU has set a target to increase energy efficiency with 20 % within 2020 as one of its measures to reduce CO2 emissions. There is also a growing interest for promoting demand response in the electricity market for better market performance (Stoft, 2002) and to reduce peak demand (Hunt, 2002). Demand response to electricity prices can be handled consistently in operational models for the electricity market models that minimize total system costs (Ruff, 2002). However, policies for reduced demand or increased flexibility sometimes result in discrete shifts in the demand curve for electricity. This paper addresses an apparently paradoxical result when such shifts are evaluated in a partial analysis of the electricity market: If the demand curve for electricity shifts downwards, e.g. because of increased efficiency of appliances, the consumer surplus may be reduced. However, the true consumer surplus cannot be reduced as a consequence of increased energy efficiency. We show how the consumer surplus must be corrected to be comparable in the two cases. This is necessary to analyse the welfare effects of policy initiatives in simulation models.

Methods

The underlying problem is the use of partial models for the electricity market. In theory, the best approach would be to include other markets in the same model. However, this is often impractical in many modelling contexts. In the paper we analyse the problem analytically for three types of shifts in the demand curve: increased energy efficiency, reduced costs for an alternative energy carrier (alternative to electricity), and revealing underlying elasticity by giving a more correct price-signal. In this abstract we illustrate two of the cases graphically:

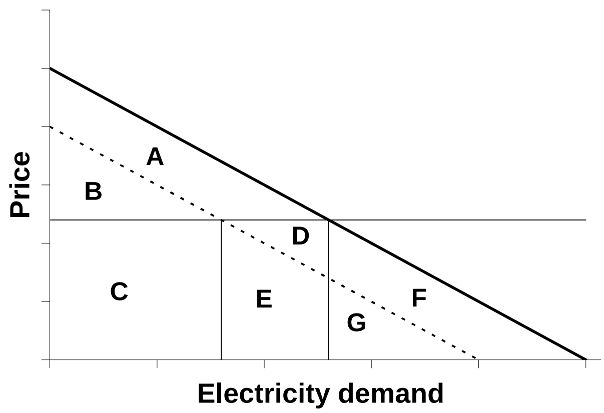

Fig. 1: Increased energy efficiency

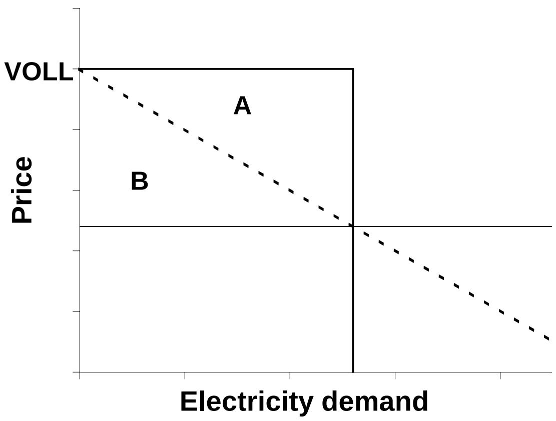

Fig. 2: Revealing underlying elasticity

The change in the social surplus after an exogenous shift in the demand curve can be divided into two separate parts. The first part is the change in surplus evaluated at the initial equilibrium price. The second part is the change in surplus for consumers and producers because of a different price in the new equilibrium. This second part is consistently accounted for using the original supply curve and the new demand curve. The first part of the calculation is addressed here.

Results

Increased energy efficiency

By using more efficient equipment, the use of electricity can be reduced without welfare-reductions. In the following we will analyse a case where the amount of electricity that is needed to obtain a given utility is reduced by a given quantity. In such cases, the whole demand curve for electricity shifts to the left, cf. Fig. 1.

The dotted curve shows the new demand curve after the shift. The consumer surplus is given by A+B before the shift and area B after the shift. Hence the consumer surplus is apparently reduced by A. The reason for the reduced consumer surplus in the Figure is that we use a partial model. The increased consumer surplus in other markets because of saved costs in the electricity market should therefore be accounted for separately. Since the utility *by assumption* is the same even though the consumed amount of electricity is reduced after the shift in the demand curve, we must add the apparent reduction in utility (the reduced area under the demand curve: A+D+E) to the new consumer surplus when we assess the welfare-effect of the increased energy efficiency. The area E is identical to area F since triangles E+G and F+G are identical. Thus, we have to adjust the new consumer surplus with A+D+F, which is the area between the old and new demand curve. In the paper a more formal derivation of this result will be given.

Revealing underlying elasticity

For most consumers, electricity consumption is metered at regular but long intervals, varying between countries from once a month to once a year. As a result, demand is completely inelastic with respect to short term price variations and this poses challenges with respect to calculating social welfare. But even though the demand curve is vertical, the cost of reducing demand is not infinite. Therefore, the so called Value of Lost Load (VOLL) is often used in models. With this approach, the demand curve becomes vertical up to VOLL, and horizontal from this point down to zero demand, and the calculated consumer surplus is the area between the price and VOLL, as shown by the solid curve in Fig. 2. The dotted curve in this Figure shows the demand curve if consumers are exposed to short term price variations by introducing hourly metering. We assume that there is no real change in the consumers' utility function, but because of the introduction of hourly metering, the real price-elasticity becomes visible in the market, and this represents the true marginal utility of the consumers. Apparently, the consumer surplus is reduced from area A+B to area B. However, this cannot be correct, because these are the same consumers consuming the same quantity. The true consumer surplus is determined by the sloping demand curve, i.e. area B, also before the shift. This means that if the inelastic curve was used to calculate consumer surplus, this must be corrected by area A which is the integral of the difference between the curves, integrated from the origin to the equilibrium quantity.

Conclusions

In partial models for the electricity market it is necessary to adjust the calculated change in the consumer surplus when assessing the effect of exogenous changes that alter the demand curve. The approach is basically the same for all cases – the consumer surplus must be corrected with the integrated difference between the old and new demand curves over the relevant quantity.

The proposed approach can easily be included in existing simulation models, and makes it possible to assess the social welfare effect of changes in demand, e.g. from increased energy efficiency or revealed demand elasticity. The proposed methodology makes it possible to consistently compare such demand side measures with increases in generation capacity.

References

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