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Comparison of different models for estimating the residential sector customer interruption costs

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ABSTRACT

Estimation of economic impacts of power interruptions in residential customers segment is a challenging and tedious task. The literature presents different methods to come up with sound calculations for these customer interruption costs. This paper makes use of a detailed customer survey study that was conducted in Finland and presents a comparison of five different models: WTA, WTP, direct worth approach, price elasticity approach and a new macroeconomic model. When doing the analysis a total of 1009 customers are divided into three sub-categories regarding the distinct characteristics of power consumptions: households, vacation houses and farm house customers.

1. Introduction

The current power system infrastructure in developed countries is quite old. Although the rate of power consumption increase is not considerably high, certain modifications and developments are needed as more renewable sources are introduced into the system. At this point the balance between further investments and acceptable level of outage events is crucial. To elaborate this point, numerous customer interruption costs analysis studies have been done for the last couple of decades.

The residential customers differ from the industrial and commercial customers in terms of power consumption characteristics. Since there is no direct economic activity linked to the continuous and high quality electricity, it is highly difficult and challenging to assess the power outage costs of the domestic consumers. Compared to the industrial and commercial customers, there has been fewer studies focusing on the residential ones. This paper aims to be a reliable source for domestic customer outage costs estimation methods.

Customer surveys are the most suitable tools to estimate the customer interruption costs (CIC) of the residential customers. The direct worth (DW) approach and the price proportional method are two main ways of conducting a customer survey. In DW approach the customers are asked to evaluate their losses in the predefined outage scenarios. On the other hand, the price proportional method includes extensively adopted Willingness to Pay (WTP) and Willingness to Accept (WTA) approaches. Ref. [1] studies the power reliability worth of residential customers by the aid of a customer survey. The paper [2] focuses on same challenge by adopting the WTP approach. A comprehensive WTP study for Swedish households is presented in [3]. Papers [4,5] follow WTP methodology for residential customers as well. The reference [6] compares the findings of DW and WTP methodologies for domestic customers. Ref. [7] includes the study of WTA/WTP findings of Flemish households. Another WTA/WTP study for German private households can be found at [8]. On the other hand, although the majority of the studies are based on customer surveys, Ref. [9] adopts a macro econometric approach to analyze the customer interruption costs of domestic customers.

This paper introduces the results of a comprehensive customer survey study conducted in Finland. It presents the comparisons of DW, WTA and WTP results. In addition, a price elasticity method and its results and the findings of a novel macroeconomic model are introduced. Instead of proposing a method that comes up with certain estimations for the residential sector outage costs, via the

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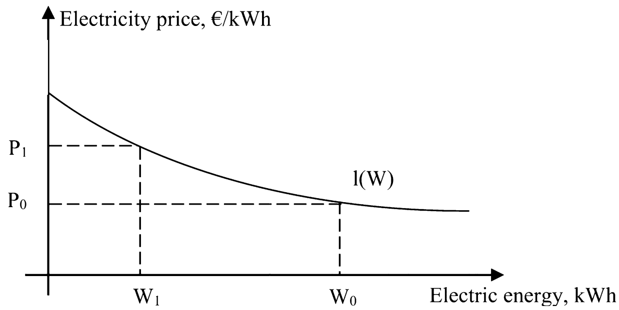

Fig. 1. The price elasticity.

novel macroeconomic model, an estimation band with maximum and minimum values is presented. The DW, WTA, WTP and price elasticity method findings are utilized for defining the boundaries to the cost estimations.

2. Interruption costs estimation methods

2.1. The direct worth approach

The DW approach includes outage scenario questions that differ in terms of the following:

- duration of the interruption,
- character of the interruption (whether the outage was reported to the customer beforehand or not),
- time of the interruption (morning, noon, evening, night),
- the season when the interruption takes place (winter, spring, summer, autumn).

The customers were asked to estimate and report their economic losses according to the above stated parameters. Then these monetary values were normalized by the average peak powers. The resulting customer damage function is designated as CIC_{DW} in €/kW.

2.2. The price proportional method

Due to geographical location Finland suffers from harsh winters. Therefore the electricity consumption peaks are seen during winters. For this reason, the highest economic impacts of possible power interruptions for the Finnish residential customers are seen during winter evenings. Under the light of this observation, the customers were asked to state a certain amount of compensation which they require to accept a scheduled 1-h outage (WTA) during winter evening time and on the other hand they were asked to report the amount of money they are willing to pay (WTP) in order to avoid the same outage. Then the monetary figures were normalized with average peak powers.

2.3. The price elasticity method

As long as the customer feels that the value of a product is greater than or equal to the price of the product, the customer receives a value added. If the price goes up, the customer customizes the amount of the product that he/she purchases. This method can also be applied when the electric energy is considered as the product. The real value of the electric power is the highest price that the customer is willing to pay. The difference between the real value of the power and the price of the power gives the value added that the customer enjoys. In case of an interruption the customer will lose some of his/her value. Fig. 1 shows the use of electricity as a function of the price of the electrical energy.

In a normal case the customer's electricity consumption is equal to W_0 where the price of the electricity is P_0. At this point the marginal value of the product is equal to the price of the product. If the electricity price rises to P_1, the customer reduces the use of electricity. Then the customer's electricity consumption is set to the point (W_1, P_1). The electricity consumption is decreased by the amount of $(W_0 - W_1)$ when the price of the electricity rises by the amount of $(P_1 - P_0)$. The lost value of the undelivered energy can be calculated from Eq. (1).

$$Loss = \int_{\Delta W} (l(W) - P_0)dW \tag{1}$$

In the survey questionnaire the customers were asked to state which electrical appliances they would not use for 3 h if 5% of the annual energy cost is offered as a compensation. During calculations P_0 was taken as 0.10 €/kWh. The points W_0, W_1 and P_1 were calculated according to the survey responses. After calculating the monetary losses, a customer damage function of CIC_{PE} in €/kW was defined via normalization by peak power.

2.4. A novel macroeconomic approach

In the paper [9] a macroeconomic approach was proposed. This model is based on the theory that one outage-hour during the leisure time corresponds to 1 h of less work during working hours and therefore the value of this lost non-working hour is equal to the wage of 1 h of work. By following the above-mentioned logic, a new macroeconomic model was derived. In this model, instead of annual energy consumption, the peak power was chosen as the normalization factor. It is calculated as follows:

$$CIC_{me} = d\frac{tw}{PP} \tag{2}$$

where, CIC_{me} is the CIC estimation via the macroeconomic approach. t is the outage duration in hours, w is the hourly wage in euros and PP is the peak power consumption in kW. d is the factor for continuous electric power dependency with $d \in [0,1]$. This factor can be calculated via the aid of a simple customer survey. The customers are asked that which electrical appliances they are willing not to use in return for a compensation. The reduction in power consumption will give an idea about the minimum requirements of a customer to carry out his/her basic needs. Then;

$$d = \frac{100\% - \%\text{ of the reduction in power consumption}}{100\%} \tag{3}$$

When inflated to 2013, the Finnish average total monthly earnings of wage and salary earners is 18.69 € per hour [10]. Furthermore, since peak power is chosen as the normalization factor in this paper, instead of energy consumption, the peak power that was reached by the customer was preferred. All CICs are presented in the unit of €/kW.

3. The customer survey

Different consumer segments have distinct power consumption characteristics and thus the economic outcomes of the power interruptions differ considerably. That is why during the survey the domestic customers were divided into three categories according to the location of the settlements. The customers who live in urban areas were named as household customers, where the ones in rural areas were named as farmhouse customers. Finally summer cottages were categorized as vacation house customers. These groups are households, holiday houses and farm houses. A total of 1009 customers were surveyed which corresponds to about 30% of response rate. The resulting customer damage functions were normalized by the peak power consumption of the customers.