The Use of a Fixed Part and a Variable Part in Heat Cost Allocation after Heat Quantity in Swedish Multiple Unit Dwellings

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SUMMARY

This is a theoretical analyse based on microeconomics. It analyses heat cost allocation methods after measured heat quantity for MU-dwellings in a building with an owner who byes or produces the heat that is sold to the households.

A MU-dwelling loses heat to the outdoor air and exchanges heat with surrounding dwellings. The owner can use less heat to increace the indoor temperature than the household it self. The household must pay for heat transfer to other dwellings. This makes an increase in the indoor temperature more expensive to the household than to the owner. The households will have a to low indoor temperature. To compensate this only a part of the measured heat quantity is sold. The rest of the heat cost for the building is distributed to the households after dwelling area. In Swedish MU-dwellings 60-80 % the fixed part should be distributed after area and 20-40 % the variable part sold after measured quantiy.

INTRODUCTION

The influence of the marginal cost on the consumed quantity of a goods has been known from economics for hundreds of years, but it has seldom been used to analyse heating of buildings. The use of a fixed part is to reduce the marginal cost of indoor temperature or to make a temperature increase cheaper. This paper suggests how the fixed part should be calculated to give indoor temperature the marginal cost that corresponds to the heat loss to the outdoor air.

[1] called heating in MU-dwellings a semi-collective goods. Semi means that the acces to the indoor temperature is limited to the membes of the households. [2] used economics to analyse individual metering of hot water in MU-dwellings. [3] presented the economics of heating. The occupants sets their thermostats to the temperature where marginal cost equals marginal value of indoor temperature. He investigated the economic differences between a common temperature and individually chosen temperatures in two apartments and used the theory for public goods to find the best common indoor temperature in a building with two dwellings. [4] used economics to investigate low indoor temperatures in low income households.

The demand curve for indoor temperature in Swedish MU-dwellings was determined by [5] as a straight line and in SU-dwellings by [6] and [7]. Heat cost allocation in homes with individual control and individual heat metering, individual temperature metering and a collective temperature was described in [8]. The use of a fixed part and a variable part for heat cost allocation after heat quantity was not included in [8]. A fixed part (grundkosten) and a variable part (verbrauchskosten) is used in Germany [9]. The fixed part there is between

30-50 % of the sum of all costs for heating including cleaning and maintenance of the heating system.

METHODS

A household in a MU-dwelling produces indoor temperature whith heat and insulation. The household balances the cost of heat or cost of temperarure horizontally marked in figure 1 and the cost of cold diagonally marked against each other. The household choses the indoor temperature where the marginal cost of heat is equal to the marginal cost of cold. The marginal cost of heat is the cost of a temperature increase.

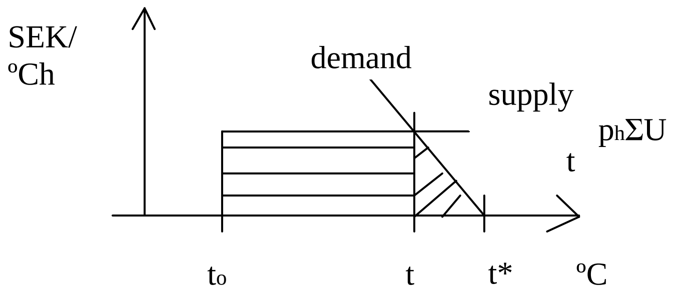

Figure 1. Demand and supply curves for indoor temperature. Indoor temperature, t. Outdoor temperature, t_o. Highest indoor temperature the household is willing to pay for, t*.

The MU-dwellings are in a building with an owner who byes or produces the heat that is sold to the households after meassured heat quantity. A MU-household in a building loses heat to the outdoor air and exchanges heat with surrounding dwellings. The owner can use less heat to increate the indoor temperaturre in a dwelling than the household it self. This makes an increase in the indoor temperature more expensive to the household than to the owner. The household must pay for heat transfer to other dwellings, but the owner only pays for the heat that goes out to the outdoor air. Heat to other dwellings repleaces heat from the heating system. The households will have a to low indoor temperature if the household pays for the heat after measured quantity.

In this case it is possible for the owner to reduce the price of heat to the household or to sell only a part of the measured heat quantity. The ideal is to make the cost of a temperature change the same as for the owner. This will increase the indoor temperature and well beeing for the households. To cover the cost of heat to the building the owner must increase the rent so his economy isn't affected. It is important that the cost of a goods or serivce is the same to all users in the society so the alternatives can be optimised against the same price. This is for the period during the year when heating is neccesary in all dwellings in the building. Three heat cost allocation methods are analysed.

The same cost for a temperature increase for both household and owner

Q is heat quantity to the building in figure 2 (W). Q_1 is the measured heat quantity (W) to dwelling 1. ΣQ_i is the sum of measured heat quantities to the n dwellings. ΣU_1 equation 1 is the specific heat demand of dwelling 1 (W/°C) for heat to outdoor air. q outdoor air rate for ventilation (m^3/s). ΣU_{12} is the specific heat exchange between dwelling 1 and dwelling 2 trough internal walls (W/°C) equation 2.

$$\Sigma U_1 = \Sigma UA + q \cdot \rho \cdot c_p \qquad (1)$$

$$\Sigma U_{12} = \Sigma UA_{int} \qquad (2)$$

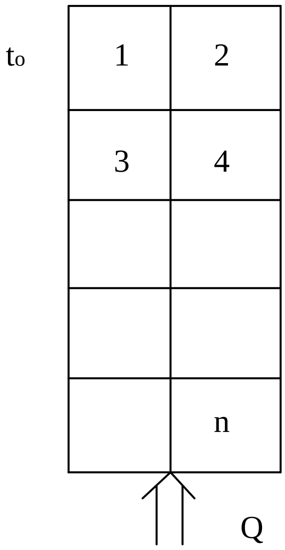

Figure 2. Building with n MU-dwellings. t_o outdoor temperature ºC.

The heat loss to outdoor air (W) from dwelling 1, equation 3. All rooms in a dwelling have the same temperature.

$$\Sigma U_1 \cdot (t_1 - t_o) \qquad (3)$$

The heat loss from dwelling 1 to outdoor air and to other dwellings Q_1, equation 4.

$$Q_1 = \Sigma U_1 \cdot (t_1 - t_o) + \Sigma\Sigma U_{1i} \cdot (t_1 - t_m) \qquad (4)$$

t_m average (weigthed) temperature in dwellings surrounding dwelling 1 (ºC). $\Sigma\Sigma U_{1i}$ is the specific heat exchange between dwelling 1 and surrounding dwellings trough internal walls (W/°C) equation 5.

$$\Sigma\Sigma U_{1i} = \Sigma U_{12} + \Sigma U_{13} + \Sigma U_{14} \qquad (5)$$

If equation 4 is differentiated with respect to t_1 and the variable share (1-Φ) times the heat demand for the household to increase the indoor temperatue is put equal to the differentiated heat demand for the owner equation 3. Then $(1-\Phi_1)$ can be solved equation 6. The fixed share Φ_1.

$$(1 - \Phi_1) = \frac{\Sigma U_1}{\Sigma U_1 + \Sigma\Sigma U_{1i}} \qquad (6)$$

If Q_1 $(1-\Phi_1)$ is sold to the houshold at the market price of heat p_h (SEK/kWh), (1USD = 8 SEK) or the price of heat is reduced to $(1-\Phi_1)$ p_h then it will be equally expensive for the household and the owner to increase the indoor temperatue in dwelling 1 but the owner will not cover his cost for heat. The measured heat quantity to dwelling 1 will still depend on the temperature in surrounding dwellings, t_m but the fixed part will reduce the influence.

Since this is a reduction in marginal cost for the household a higher indoor temperature will be used by the household. There is another variable share for dwelling 2.

The same cost for a temperature increase for both household and owner that covers the cost for the owner

If the price of heat or the sold quantity of heat is reduced then the owner must increase the rent to cover his costs.

The heat to dwelling i, Q_i is divided in two parts with the fixed share Φ_i for dwelling i in equation 7.

$$Q_i = \Phi_i \cdot Q_i + (1 - \Phi_i) \cdot Q_i \qquad (7)$$

All heat that the owner byes or produces Q will be sold to the households according to equation 7 and 8.

$$Q = \Sigma Q_i = \Sigma \Phi_i \cdot Q_i + \Sigma(1 - \Phi_i) \cdot Q_i \qquad (8)$$

Each household pays p_h (1 - Φ_i) Q_i as the variable part. The rest of the heat $\Sigma\Phi_i$ Q_i is equally divided between the n dwellings since they have the same area. This is called the fixed part and it is included in the rent.

The marginal cost of indoor temperature now depends on the number of dwellings n in the building so a new Φ_1 analog to equation 6 have to be derived. .

Household 1 pays for the heat quantity Q_{p1} according to equation 9.

$$Q_{p1} = \frac{\Sigma \Phi_i \cdot Q_i}{n} + (1 - \Phi_1) Q_1 \qquad (9)$$

The new Φ_1 should make the differential of Q_{p1} with regard to t_1 equal to ΣU_1 according to equation 3. This makes the marginal cost for the household in dwelling 1 equal to the marginal cost for the heat loss to the outdoor air. Q_1 from equation 4, Q_2 - Q_4 are analog to equation 4 and inserted in equation 9. Dwelling 2, 3 and 4 have heat exchange with dwelling 1.

If Φ_1 to Φ_4 are approximately equal then Φ_1 can be calculated from equation 10. This approximation is probably a better method than to use the same average Φ for all dwellings. Different Φ makes the marginal cost equal to the marginal cost for the heat loss to the outdoor air for every dwelling.

$$\Phi_1 = \frac{\Sigma\Sigma U_{1i}}{\Sigma U_1 \cdot \left(1 - \frac{1}{n}\right) + \Sigma\Sigma U_{1i}} \qquad (10)$$

Compared to the fixed share from equation 6, equation 10 gives a higher fixed share. It will be higher in buildings with a few dwellings.

The same cost for a temperature increase, the same cost for heating for both household and owner and that covers the cost for the owner

This is not possible with heat quantity measurement since the heat to other dwellings depends on the temperature in the surrounding dwellings and on the heat transfer properties to the other dwellings equation 4.

Heat quantity measurement will give a reduced cost for the household if heat from internal heating systems or free heat are used in the dwelling. But the variable part will reduce the part of the free heat that reduces the cost.

A cost allocation system that gives the same cost for a temperature increase, the same cost for heating for both household and owner that covers the cost for the owner is indoor temperature measurement and calculation of the heat to the outdoor air from the dwelling with equation 3. This system can not register the free heat.

Example

The heat to and from a MU-dwelling can be shown as function of the indoor temperature in a diagram figure 3. The dwelling get heat from heaters and depending on the indoor temperature exchanges heat with other dwellings. The dwelling also get heat from its occupants, from lighting, refrigerators etc. This is called free heat. If the heaters in the dwelling is shut of it will get the indoor temperature t_b. At higher temperatures the heaters are used. At the indoor temperature t_m there is no net heat exchange with other dwellings and at higher indoor temperatures heat is lost to other dwellings.
The line representing heat loss to the outdoor air starts in t_o. At t_b the line is thick. This part shows the heat power that a dwelling pays for if the marginal cost of temperature is for the heat loss to the outdoor air. The horizontal thick line shows the fixed part.

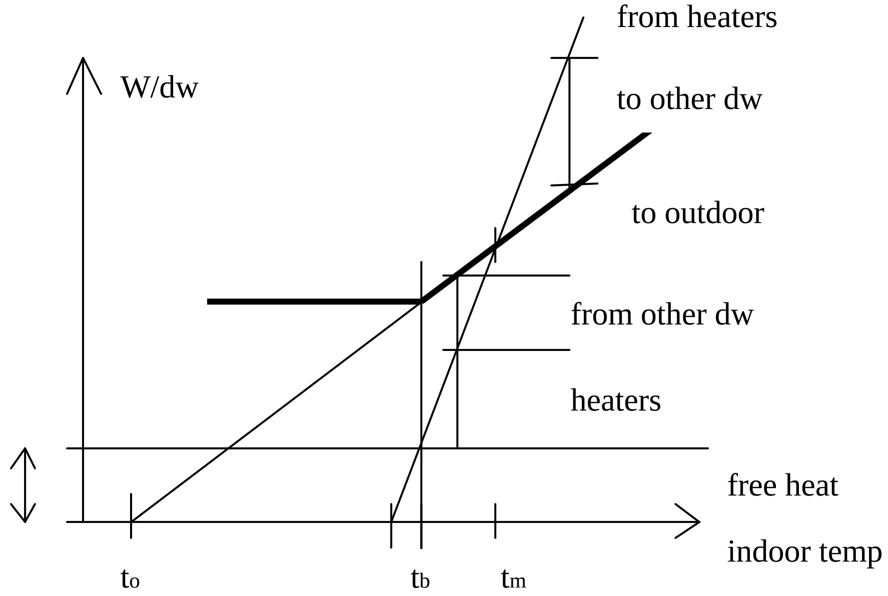

Figure 3. Heat to and from a MU-dwelling with free heat.

The heat from the heaters is more sensible to the indoor temperature than the heat loss to the outdoor air. If the heat from the heaters should be used for cost allocation then it must be corrected with Φ so the heating cost follows the cost for heat loss to the outdoor air, from t_b and up to higher temperatures. At the lowest possible temperature t_b the household pays the fixed part of the buildings heating cost.

RESULTS

Calcualtion of the fixed share Φ that gives the same cost for a temperature increase for both household and owner in Swedish MU-dwellings built before and after the energy crisis.

Table 1 Heat loss from a MU-dwelling to outdoor air trough different building elements.

Element		Built after 1980		Built bef 1975	
	Area m^2	U $W/m^{2o}C$	ΣUA W/ºC	U $W/m^{2o}C$	ΣUA W/ºC
Wall	31	0.3	10	0.8	25
Roof	70	0.2	14	0.6	42
Window	10	2.0	20	3.0	30
Ventilation		25 l/s	30	30 l/s	36
Sum		ΣU W/ºC	74	ΣU W/ºC	133

Table 2 Heat exchange between MU-dwellings $\Sigma\Sigma U_{1i}$

	Area m^2	U $W/m^{2o}C$	ΣUA W/ºC
Wall	41	2.5	102
Floor	70	1.5	105
Sum		$\Sigma\Sigma U_{1i}$ W/ºC	207

The ΣU_1 from table 1 and $\Sigma\Sigma U_{1i}$ from table 2 in equation 6 gives the Φ in table 3. If the building have preheated supply air then the heat demand for ventilation in table 1 is excluced.

Table 3 Fixed share Φ that fullfills the same marginal cost for both owner and household. In a MU-dwelling according to table 1 and 2. Variable share (1- Φ).

	Built after 1980	Built before 1975
Exhaust ventilation	74 %	61 %
Supply and exhaust vent	82 %	68 %

The Φ that gives the same cost for a temperature increase for both household and owner and that covers the cost for the owner to be used with equation 9 will be higher than in table 3 depending on how many dwellings there are in the building.

To calculate a Φ for all dwellings in the building that gives the same cost for a temperature increase for both household and owner and that covers the cost for the owner more data for the building must be known, but the fixed share will be of the same magnitude as in table 3. The fixed share used in Germany is between 30-50 %.

DISCUSSION

Well insulated buildings where the dwellings have a small heat loss to the outdoor air needs a high fixed part to reduce the marginal cost of temperature. The heat exchage with the outdoor air is a small part of the total heat exchange for a MU-dwelling. Small not so well insulated buildings needs a low fixed part since the heat exchage with the outdoor air is a big part of the total heat exchange for the dwelling.

More numeric calculations and data are necessary to find the fixed part for all equaly sized dwellings that cowers the cost for the owner. More research is necessary to find the best fixed part in a building with dwellings that differs in size.

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