

DEMAND CURVE FOR INDOOR TEMPERATURE IN SWEDISH SINGLE UNIT DWELLINGS

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Summary The demanded indoor temperature in Swedish dwellings can be expressed as a function of the marginal cost of indoor temperature and of the disposable income of the household. The function shows that the temperature in multiple unit dwellings is higher than in single unit dwellings. The indoor temperature increases with increasing disposable income. The function can also be used to prognosticate the indoor temperature at given economic conditions, but more data are needed to check the validity.

Keywords: indoor temperature, economics, dwellings, demand, prognosis

INTRODUCTION

According to economics the demand curve represents the relationship between quantity demanded and price, other things being equal. The quantity demanded is the demanded indoor temperature. The price is the price of indoor temperature or the marginal cost for heating with regard to indoor temperature for a dwelling during a year, MK. This is also the differential of the heating cost with regard to the indoor temperature. The supply curve shows the price of indoor temperature at different indoor temperatures. The indoor temperature where supply meets demand is the demanded indoor temperature, t_d figure 1.

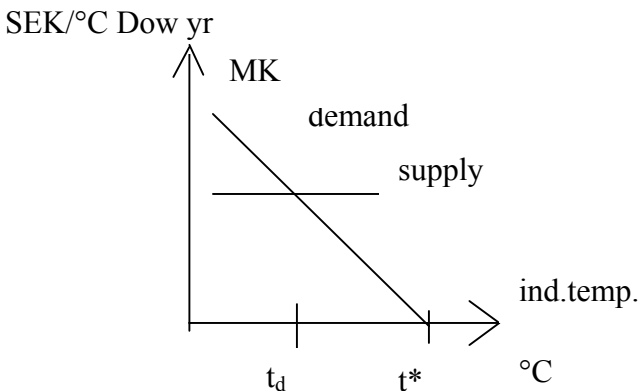


Figure 1 Demand, supply and demanded indoor temperature, t_d .

METHODS

The demanded indoor temperature is not only a function of the MK, but also a function of the disposable income of the household, DI. The demanded indoor temperature is assumed to follow the function below (1). It has been used in [1].

$$t_d = t^* - MK / DI \quad k \quad (1)$$

k and t^* can be found if demanded indoor temperatures, t_d are correlated to MK/DI. Since both MK and DI are calculated in the same value of money, the inflation will be reduced. MK and DI are calculated per household.

In a single unit dwelling one household is living in one dwelling and they have control over their indoor temperature and they pay for their heating independent of other households.

In Swedish multiple unit dwellings there is one household in one dwelling and they must have the same indoor temperature as the other dwellings in the building. The households pay the heating in relation to the area of their dwelling to the area of all dwellings in the building. This is collective heating, collective heat measurement and collective payment.

Disposable income

The disposable income per multiple unit dwelling and per single unit dwelling is calculated by Statistics Sweden. Here it is approximated with 0.8 GNP/cap in multiple unit dwellings and with 1.36 GNP/cap in single unit dwellings since DI-data are not available for every year when indoor temperature measurements have been done.

Marginal cost

MK (2) is calculated with data from Statistics Sweden and from the assumption that the oil-consumption should increase with 7 % if the indoor temperature is increased 1°C. The oil consumption for a dwelling is calculated from area of dwelling and specific consumption per area unit. The area of a single unit dwelling is 140 m². 80 % of the oil consumption is used for heating of the building and 20 % for hot water heating.

The price of oil is a consumer price including tax. This is a simplification since oil heating has been successively replaced by electric heating and district heating. The price of oil 1952 is estimated from the price of oil 1955 and from the price relation of fire-wood 1955 and 1952.

$$MK = \text{price of oil (SEK/m}^3) * \text{spec cons. (m}^3/\text{m}^2 \text{ yr)} * \text{area (m}^2/\text{dw)} * (1 - \text{hot water)} * 7 \% / ^\circ\text{C} \quad (2)$$

Demanded indoor temperatures

The demanded indoor temperature is from measurements by the Swedish Institute of Building Research. The measurements from 1982-85 and 1992 were randomly distributed over the whole country so they are national averages of the indoor

temperatures in Sweden. The measurements from 1952 and 1965 are only from buildings in one city but since no systematic variation of the indoor temperature was discovered 1982-85 and 1992 then the values from 52 and 65 are used as national averages. The value from 1971 is an estimate. The results are given in figure 2.

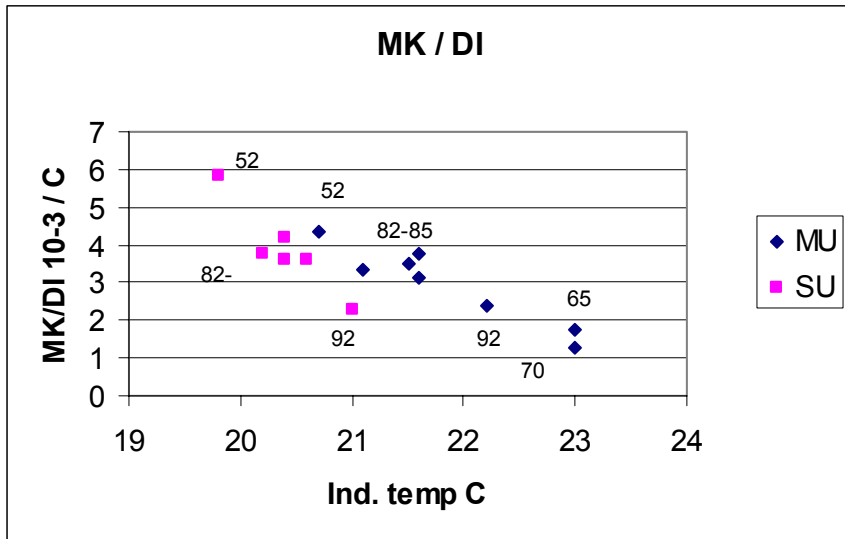


Figure 2 Marginal cost, MK for indoor temperature per year in a single unit, SU resp. in a multiple unit dwelling, MU divided by the disposable income, DI for the household in the dwelling against demanded indoor temperature

MK/DI are correlated against the demanded indoor temperature, t_d . In Single unit dwellings (3) and in Multiple unit dwellings (4).

$$MK/DI = 2.75 \cdot 10^{-3} (21.65 - t) \quad r = 0.95 \quad (3)$$

$$MK/DI = 1.19 \cdot 10^{-3} (24.10 - t) \quad r = 0.94 \quad (4)$$

The demanded indoor temperatures have followed two lines one for SU and one for MU. The indoor temperature went up from 1952 to 1965-70 then down to 1982-85 and then up to 1992. The path between 82-85 and 92 in the diagram has been passed three times in different directions in 40 years. There are no demanded indoor temperatures with very low MK/DI so the demand curve is perhaps not linear to zero marginal cost.

Demand curves

The demand curves for indoor temperature 1992 were in SU (5) and MU dwellings (6).

$$MK = 618 (21.65 - t) \quad (5)$$

$$MK = 155 (24.1 - t) \quad (6)$$

The indoor temperature in MU is higher than in SU and the demand curve for SU has about 4 times higher inclination than the demand curve for MU. The higher inclination means that the indoor temperature in SU are less sensitive to price changes than in MU.

Earlier estimates of the demand curve

[2] presents data from a Better Insulated House program 1985 in UK where additional insulation reduced the marginal cost from 66 to 44 £ /°C dw yr, witch increased the indoor temperature from 12.9°C to 14.4°C. The dwellings were individually heated. The demand curve in table 1.

[3] is using indoor temperature in MU dwellings in Chicago and Los Angeles as an example in economics. His diagrams says that an increase in MK of 0.10 \$/°F day reduces the indoor temperature with 10°F. This gives the demand curve in table 1. $t^* = 75^\circ\text{F} = 23.9^\circ\text{C}$

Table 1 Inclination of demand curves and t^* .

Location, period	Incl. dem. curve SEK/°C ² dw yr	t^* °C
Chicago, LA, MU 1986	73	23.9
UK, 1985	190	17.5
Sweden, MU 1992	155	24.1
Sweden, SU 1992	618	21.65

The inclinations from 1985 are lower than from 1992 and individually heated dwellings have a higher inclination. t^* for individually heated are lover than for collective heating.

RESULTS

The design indoor temperature is used to determine the optimal insulation thickness and is a basis to determine the profitability of energy saving equipment like 3-glass windows and heat recovery ventilation. The MK/DI relations can be used to prognosticate the indoor temperature and get a design indoor temperatures that includes the increase of the indoor temperature that comes in the future.

The GNP/cap was 258 000 SEK/yr and the oil price was 6740 SEK/ m³ in Sweden year 2002. This gives an indoor temperature in SU at 21.0°C and in MU at 22.4°C according to the lines of regression. The relation between GNP/cap in Sweden and Lithuania 2002 was 6.8. The relation between price of energy in Sweden and Lithuania is assumed to be 2.5 mainly due to the high taxes on

energy in Sweden. This gives an indoor temperature of 19.9°C in SU dwellings in Lithuania if the differences in size and insulation standard between Sweden and Lithuania compensates each other. The indoor temperature in MU in Lithuania ought to be 19.5°C if the houses have collective heating, collective heat measurement and collective payment and if the differences in size and insulation standard compensates each other.

If the economic growth in Lithuania will be 4 % per year and if the price of energy is fixed (in fixed value of money) then the indoor temperature will be 20.5°C in SU and 21.0°C in MU year 2012.

DISCUSSION

Indoor temperature in Swedish dwellings 1952 -1992 is correlated to the relation between marginal cost of heating and disposable income per household.

The line of correlation can be used to prognosticate the indoor temperature at given economic conditions. More data over indoor temperatures and economic conditions is necessary to verify if the indoor temperature in other countries follow the same lines of correlation as in Sweden.

NOMENCLATURE

MK	Marginal cost with regard to indoor temperature in a dwelling one year, SEK /°C dw yr
DI	Disposable income in a dwelling one year, SEK / dw yr
k	constant
t_d	Demanded indoor temperature, °C
t	Indoor temperature, °C
t^*	Indoor temperature if heating was free, °C
dw	dwelling
GNP	Gross National Product
MU	Multiple Unit dwelling (apartment)
SEK	Swedish Kronor, 13 SEK / 1 £, 9 SEK / 1 USD
SU	Single unit dwelling

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