THE INFLUENCE OF CLIMATE ON FIRE DAMAGE

HANS ANDERSSON

Lidingö, Sweden

In his paper "Actuarial Activity in General Insurance in the Northern Countries of Europe" L. Wilhelmsen [1]) gives amongst other things an account of the work carried on by *Centralstället för nordisk ömsesidig Brandförsäkringsstatistik* (CNÖB, the Northern Central Office for Fire Insurance Statistics from Mutual Companies). In this he states that one part of the organisation's work is the carrying out of special investigations of current problems with material collected on each occasion for the purpose.

The object of this paper is to report investigations carried out in CNÖB on the connection between temperature and risk premium in fire insurance [2]). The material used is made up exclusively of civil risks (buildings) and the material has been taken from Sweden and Norway. The background to the investigation consists in the fact that in Scandinavia the risk premiums for fire insurance show an apparent geographical variation, in that the amount clearly increases in the most northerly provinces.

As we know that the fire damage directly or indirectly caused by heating systems (chimney fires, cracked building blocks, embers from fireplaces or chimneys etc.) represents a large proportion of the damage in civil risks (40-50 %, in some materials 60 % or more), that the proportion is greatest in the northern parts and that in the Swedish material about 50 % of the damage in any one area falls in the four months December to March, it is quite reasonable to trace the influence of the temperature factor behind the geographical variation; the colder the climate, the more lighting of fires and the more damage. This line of argument is connected exclusively to the frequency of damage; we shall return later to the mean degree of damage.

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[1]) The Astin Bulletin, Vol. I, Part I, Dec. 1958, p. 26.

[2]) Nordisk Brandförsäkringsstatistik, häfte 7, 1956.

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CNÖB then investigated *the firing claims frequency* $\bar{q}_e$, i.e. the frequency of damage from the causes mentioned above. It turned out that $\bar{q}_e$ in wooden houses could be regarded as proportional to the sum insured s, whilst in houses of stone or brick it is proportional to s to begin with but afterwards does not increase as much. CNÖB arrived at the following model:

$$\bar{q}_e = \begin{cases} A's \text{ in wooden houses} \\ A'' \log s + B \text{ in houses of stone or brick} \end{cases} \tag{1}$$

We now start from an insurance portfolio consisting of V_i buildings with the insured amount s_i and $i = 1, 2, 3\ldots\ldots,$ n. The expected number of cases of damage will then be:

$$m_k = \begin{cases} A' \sum\limits_i V_i \, s_i = A'F' \text{ in wooden houses,} \\ A'' (\sum\limits_i V_i \log s_i + C \sum\limits_i V_i) = A'' F'' \text{ in houses} \\ \qquad\qquad\qquad\qquad\qquad\qquad \text{of stone or brick} \end{cases} \tag{2}$$

where $C = B/A''$; F' is the volume of insurance and is accordingly obtained directly from the material. But F'' can also be calculated without difficulty if C is known. The CNÖB investigation was aimed at finding the connection between A and the temperature. As regards houses of stone or brick, it was assumed that the possible action of the temperature takes place proportionately on A'' and B, for which reason C was fixed from the total material. As in what follows the method is the same for houses of stone or brick and wooden houses, we discard in the following formulae the markings (′) and (″).

Sweden was then divided into 30 and Norway into 10 districts with one or more meteorological stations in each district. The F-values per district, the number of claims and the monthly mean temperature at the meteorological stations were noted for each month during the observation period (1946-1950); in cases in which there were several stations in the same area, a certain average of these was calculated, in which regard was paid in weighting to the distribution of the insurance portfolio in the area. The task was then to investigate the correlation between A determined as the quotient between m_K and F estimated by the observed number of claims, on the one hand, and the temperature t, on the other.

This was carried out in parallel in two ways, called in what follows Method I and Method II.

We designate the year by a, the month by b and the district by c. In "Method I" the correlation coefficient $r\ (A\ bc, t\ bc)$ was calculated, i.e. the calculations were carried out on monthly averages over the whole observation period. In "Method II" $r\ (A\ abc,\ t\ abc)$ was calculated, i.e. the calculations were carried out on the material divided up by years in which damage occurred. The results were as follows:

			r
Wooden houses,	Norway,	Method I	- .32
Wooden houses,	Sweden,	Method I	- .62
Wooden houses,	Sweden,	Method II	- .46
Houses of stone or brick,	Sweden,	Method I	- .43
Houses of stone or brick,	Sweden,	Method II	- .28

All these values differ significantly from zero, i.e. there exists a correlation in the expected direction.

By comparing r_1 with r_2 (in what follows the indices 1 and 2 indicate the two methods), we have a possibility of distinguishing the annual variation and the geographical one. We assume that A_2 and t_2 can be divided up [1]) according to the following equations:

$$\begin{aligned} A_2 &= A_1 + A_3 \\ t_2 &= t_1 + t_3 \end{aligned} \tag{3}$$

where A_1 and t_1 are only dependent on geographical position (latitude and distance to the sea) and month and A_3 and t_3 only on the year. We furthermore assume that (A_3, t_3) is independent of (A_1, t_1) and that $E(A_3) = E(t_3) = 0$. If the theoretical correlation coefficients between A_1 and t_1, between A_2 and t_2 and between A_3 and t_3 are called respectively ρ_1, ρ_2 and ρ_3 we now obtain:

$$\frac{\rho_2}{\rho_1} = \sqrt{\frac{\mathrm{Var}(A_1)\ \mathrm{Var}(t_1)}{\mathrm{Var}(A_2)\ \mathrm{Var}(t_2)}} \cdot \frac{E(A_1\, t_1) - E(A_1)\, E(t_1) + E(A_3\, t_3)}{E(A_1\, t_1) - E(A_1)\, E(t_1)} \tag{4}$$

$$\begin{cases} \mathrm{Var}\ A_3 = \mathrm{Var}\ A_2 - \mathrm{Var}\ A_1 \\ \mathrm{Var}\ t_3 = \mathrm{Var}\ t_2 - \mathrm{Var}\ t_1 \end{cases} \tag{5}$$

[1]) Cf. H. Wold, A Study in the Analysis of Time Series, Uppsala 1938, p. 200

$$\rho_3 = \frac{E(A_3\, t_3)}{\sqrt{\text{Var}\, A_3\, \text{Var}\, t_3}} \tag{6}$$

We interpret the values of averages, variances and correlation coefficients obtained from the empirical calculations as approximations to the corresponding theoretical figures and introduce them into equations (4) - (6). We calculate $E(A_3, t_3)$ from (4), and Var A_3 and Var t_3 from (5), after which (6) yields an empirical value of the correlation coefficient r_3 between A_3 and t_3. The results are as follows:

		r_3
Wooden houses,	Sweden	- .33
Houses of stone or brick,	Sweden	- .26

These values are approximately half as large as the corresponding figures relating to Method I (r_1). From this it follows that that part of the firing claims frequency which is dependent on district and month of damage is more sensitive to temperature variations than that part which is dependent on year of damage.

Finally we shall also reproduce the connections obtained between $\bar{q}_e$, s and the annual mean temperature T by using elementary regression analysis between A and t.

Wooden houses, Norway, $s < 200.000$, $\bar{q}_e = (9.25 - .41\, T)\, .10^{-8}.s$
Wooden houses, Sweden, $s < 225.000$, $\bar{q}_e = (27.84 - 1.84\, T)\, .10^{-8} s$
Houses of stone or brick, Sweden, $s < 1.000.000$, $\bar{q}_e = (24.48 - 1.27\, T) . 10^{-3} . ({}^{10}\log s - 4.139)$ (7)

The difference between the Norwegian and the Swedish wooden houses is due, on the one hand, to the fact that the risk classes are not identical (the Norwegian material had reference to risks in the countryside, the Swedish to risks in urban communities) and on the other, to the fact that in the one case s is measured in Norwegian kronor and in the other in Swedish kronor. — T is measured in Celsius degrees.

It must be strongly emphasized that the formulae in (7) are only very rough first approximations. They cannot be used for direct premium fixing. Their practical significance lies in the information they can yield as regards the most suitable line of demarcation between different geographical tariff areas—in so far as the climatic factor will influence this.

The following table is reproduced from some values which show the firing claims frequency according to (7) in thousands for various localities in Sweden (wooden houses insured for 100.000 kronor):

Name of locality	Latitude of locality	T	$1000\ \bar{q}_e$, according to (7)
Karesuando	68° 27′	-2.3	31.5
Haparanda	65° 50′	1.0	25.6
Östersund	63° 12′	2.4	23.4
Stockholm	59° 20′	5.9	17.0
Kalmar	56° 39′	7.0	15.0
Lund	55° 43′	7.3	14.4

We now pass on to *the mean degree of damage*. The various statistical materials which are available hardly yield any unambiguous instances of any great geographical differences between the different geographical districts, though sometimes rather higher values could be observed in the northern ones. This circumstance has aroused some surprise, bearing in mind the difficulties encountered by a fire brigade when both departure and the work of extinguishing the fire have to be done in cold weather. However, a recent Swedish investigation (observation period: 1956-1959)—not yet published by CNÖB—explains the matter more fully. According to this *the number of claims* was distributed *as percentages* by causes of damage in accordance with the table below:

Cause of damage	D I		D II		D III	
	B 1	B 2	B 1	B 2	B 1	B 2
Chimney fire..........	36	37	25	43	15	19
Damage due to lighting fires in other respects	16	17	18	18	25	19
Other causes..........	48	46	57	39	60	62
Total	100	100	100	100	100	100

D indicates three different parts of the country:
I = northern Sweden, II = central and III = southern Sweden.

B indicates two different grades of fire protection:
1 = the best fire protection, 2 = fair average fire protection.
(Others could not be dealt with for lack of adequate material.)

Only *wooden* houses were observed.

A closer study of the absolute figures shows that there exists a significant difference between the distributions D I and D II, on the one hand, and D III, on the other. The difference is essentially in the higher frequency of chimney fires in D I and D II. As it is now known that chimney fires have on the average a lower mean degree of damage than other kinds of fire damages, we have consequently discovered a phenomenon which at least partly neutralizes the supposed increase in the mean degree of damage in the northern parts of Sweden.

We reproduce below a table of *estimated mean degrees of damage**); the figures are made relative, in that the value for D III has been set throughout at 100, after which other figures were converted in proportion.

The material used is too small for it to be possible to consider the figures in this table as representative, for which reason the table must only be regarded as a numerical example, communicated for the purpose of giving an illustration of what has been said. Only wooden houses were observed.

B	D	Estimated mean degree of damage: With observed distribution of cause of damage	Estimated mean degree of damage: With distribution of cause of damage as in D III
1	I	124	155
	II	126	147
	III	100	100
2	I	116	130
	II	112	158
	III	100	100

There is in the material studied a certain increase as between southern and northern Sweden, but it is clear that this would have been substantially greater without the trifling chimney fires.

*) The primary material was grouped by cause of damage, district, grade of fire protection and interval following amount of fire insurance. By calculating certain weighted averages, an attempt was made to neutralize the effect of different distributions of amounts of fire insurance for damaged buildings in the different classes.

The CNÖB investigations of the importance of climate in fire damage in civil-risk buildings in Norway and Sweden can be summarized in this way:

(1) Chiefly climatic factors are behind the geographic variation in risk premium.

(2) The risk premium increases with falling annual mean temperature and the same tendency applies to both frequency of damage and mean degree of damage.

(3) The increase in mean degree of damage is checked by the fact that chimney-fire damage, the scope of which is as a rule small, grows more rapidly in frequency than other kinds of damage. On this account the temperature factor comes to the forefront, chiefly on the side of frequency of damage.

(4) By using a rough first approximation, the frequency of damage due to lighting fires can be represented as a function of the amount insured and annual temperature by means of formulae of the (7) type.

(5) That part of the frequency of damage due to lighting fires which is dependent on district and month of damage is more sensitive to temperature variations than that part which is dependent on year of damage.