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Christian Pfister

Climate and Economy in Eighteenth-Century

Switzerland Only recently have historians begun to analyze the relationship between climatic and economy. Utterstroem's study represents one of the first attempts to examine systematically the effects of climatic fluctuations upon population changes. Le Roy Ladurie, in Times of Feast, Times of Famine, deals mainly with the physical aspect of climatic history, which is regarded as the basis for the study of ecological history. However, surprisingly few studies have gone beyond sheer descriptions relating weather conditions to fluctuations in yields, food prices, and mortality. The most important are those of Titow and Jones on England and that of Post on early nineteenth-century Europe.[1]

Most economic historians have been reluctant to investigate the significance of meteorological patterns for economic and demographic behavior. This is probably because they are not familiar with the basic theories and data sources. Further, experience in modern Europe and America suggests that weather is no longer an important influence on economic change, although recent events indicate a reappearing vulnerability of man's economy and society to climatic variation.

Societies in which agriculture represented a large proportion of economic output were much more concerned about fluctuations in weather. In their chronicles, remarkable meteorological events are frequently mentioned and often related to harvest failures, starvation, and high mortality. Despite their colorful exag-

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1 Gustav Utterstroem, "Climatic Fluctuations and Population Problems in Early Modern History," *Scandinavian Economic History Review*, III (1955), 3–47; Emmanuel Le Roy Ladurie, *Times of Feast, Times of Famine: A History of Climate Since the Year 1000* (Garden City, 1971), 24; John Titow, "Evidence of Weather in the Account Rolls of the Bishopric of Winchester 1209–1350," *Economic History Review*, XII (1960), 360–365; Eric L. Jones, *Seasons and Prices. The Role of the Weather in English Agricultural History* (London, 1964); John D. Post, "A Study in Meteorological and Trade Cycle History: The Economic Crisis Following the Napoleonic Wars," *Journal of Economic History*, XXXIV (1974), 315–349.

gerations and retrospective inaccuracies, this evidence should not be rejected until subjected to detailed examination.

Weather , as related to human history, must be studied pri- marily with respect to its impact on crops. Agrarian theory points out that yields per acre vary according to the nature and sequence of weather patterns to which a plant is exposed du ring its growth. Large fluctuations are most often due to deviations frorn usual meteorological conditions. The impact of the weather depends on the stage of growth of the plant.2 Any atternpt to measure the influence of meteorology on human history must therefore begin with an analysis of the distribution and the sequence of climatic extremes. In this article the term "rneteorological stress" will be used to describe a major impact of weather upon agrarian pro- duction. The darnage may stern frorn shocks like heavy frosts or haiistorms, as well as frorn such longer lasting situations as rainy summers or cold winters. The meteorological explanation ofbad crops is the basic approach used to determine the impact of me- teorology on human history.

The focus on weather-crop relationships provides a useful tool for the analysis of subsistence crises. It is well known that these crises became less frequent and less violent in Western Eu- rope after the early eighteenth century. The rising tide of popu- lation is credited to improvernents in health care, transportation, and administration, but we may well ask whether or not a less- ening in frequency and magnitude of the meteorological stress was also involved. Further, in this period man had lowered the meteorological vulnerability of agriculture through the introduc- tion of new crops, particularly the potato.3 To w hat extent can this new ecological equilibriurn account for the reduction in the mortality peaks?

We are far frorn having reliable data with which to analyze so broad an issue. However, I have atternpted to cast light on the relationship between weather, crops, and population change by a detailed study of a small country-Switzerland-for a limited

2 U.S. Dept. of Agriculture, *Climate and Man* (Washington, D.C., 1941), 292; Hans Baumann, *Witterungslehre fuer die Landwirtschaft* (Berlin, 1961), 25 ff.

3 Jean Meuvret, "Les crises de subsistences et la démographie de la France d'Ancien Régime," *Population*, I (1964), 643–650; William L. Langer, "American Foods and Europe's Population Growth 1750–1850," *Journal of Social History*, VIII (1975), 51–66.

time period-the second half of the eighteenth century. By con- sidering the Swiss case in the European context, I have formulated several hypotheses which deserve more attention on the part of
.economic historians than has generally been given.

Two aspects require comment. One important issue concerns the reliability and validity of the data. Where thesc arc apparcntly derived from direct measurement and observation, as in meteor- ology, their reliability must still be checked. Wherc we do not have direct measures and require the use of proxies, such as the amount of tithes paid in kind, the validity of the data needs to be demonstrated .

Another feature to which attention must be given is ecological interaction-interrelationships between fluctuations in the out-
put ofbasic foodstuffs such as grain, potatoes, and dairy products, which may either mitigate or magnify the fluctuations in specific commodity prices, and in food resources a vailable .The extent to which these ecological interactions account for discordances and inconsistencies among harvest patterns, price fluctuations, and demographic behavior must be investigated.

Both scientists and amateurs in eighteenth-century Switzer- land have left measures ofbarometric pressure, temperature, and precipitation. The basic series on barometric pressure and tem- perature beginning in 1755 have been processed by meteorolo- gists. Isolated series on rainfall go back to 1708 , but their reliability is difficult to check. For about a decade after 1760 parallel meas- J.1rements exist which make possible the use of correlation tech- niques. The relationship between the precipitation measured by two stations should be more or less constant over time. Thus, if the correlation coefficients of the monthly totals are roughly the same for the eighteenth and the twentieth century, we can pre- sume the absence of major biases.4

In most cases, however, we cannot expect to find rainfal1 measurements, to say nothing of paral1el series. Therefore, we must try to complement these with the use of weather diaries.

4 M. Bider, M. Schüepp, and H. von Rudloff, "Die Reduktion der 200jaehrigen Basler Temperaturreihe," *Archiv fuer Meteorologie, Geophysik und Bioklimatologie*, B, IX (1958), 360–412; Christian Pfister, *Agrarkonjunktur und Witterungsverlauf im westlichen Schweizer Mittelland 1755–1797* (Berne, 1975). See esp. 56 for a description of the type of instruments used, and 53–54 for a correlation matrix of the measurements.

This type of evidence is more frequent and closer to the mind of the historian than are the scientific measurements. Weather diaries can easily be quantified by counting the frequencies of events like rainfall, snowfall, sunny and foggy days, and thunderstorms. Whether it pays to attempt the cumbersome operation of counting depends on the quality of the observation. If the daily weather is characterized only by single words like "rainy ," or "sunny" we may assume that the observer did not include the weather during the night or minor rainfalls. Our estimates of the number of rainy days could therefore be too low. Comparisons of frequencies based on qualitative data with frequencies based on measurements provide a useful check of re1iability. We may again rely on the assumption that the meteorological framework does not change dramatically over time .

Table I shows that the estimates of the annual average number of rainy days, based on descriptive information in weather diaries, come close to the average numbers computed by meteorological measurement in the nineteenth and twentieth centuries. The month1y frequencies among the three stations are highly correlated and significant for both descriptive observations and measurements (Table 2). In addition to rainfall, the duration of the snowcover turned out to be crucial in influencing harvests. Fortunately the formation and dissolution of snowcover was so

Table 1 Annual average numbers of rainy days, Switzerland[a]

LOCATION	PERIOD OF OBSERVATION	ANNUAL AVERAGE NUMBERS OF RAINY DAYS
Berne	1777–1789	150.4
(alt. 572m)	1864–1930	148.3
Geneva	1768–1797	126.2
(alt. 430m)	1864–1930	131.2
Basel	1768–1797	156.1
(alt. 317m)	1864–1930	147.1

SOURCES: H. Uttinger, "Die Niederschlagshaeufigkeit in der Schweiz," *Annalen der Meteorologischen Zentralanstalt,* LXIX (1932), 1–8. Pfister, *Agrarkonjunktur,* Table 5.

a The averages for the eighteenth century are based on qualitative data in manuscript sources. The averages for the nineteenth and twentieth centuries are based on measurements (they include all days with more than 0.3 mm of precipitation).

Table 2 Matrix of correlation among monthly number of rainy days in the eighteenth and twentieth centuries

	BERNE CORRELATED WITH:				GENEVA CORRELATED WITH:			
	N 1	N 2	r 1	r 2	N 1	N 2	r 1	r 2
Basel	230	720	.85*	.84*	319	720	.81*	.75*
Geneva	144	720	.84*	.79*				

Legend: N 1 Number of paired monthly observations for the eighteenth century (Berne, 1777–1789; Geneva, 1768–1797; Basel, 1768–1797).

N 2 Number of paired monthly measurements in the period 1900–1960.

r 1 Coefficients of correlation for the eighteenth-century observations.

r 2 Coefficients of correlation for the measurements 1900–1960.

* Significant at .001 level.

The above monthly averages for the eighteenth century are based on qualitative data in manuscript sources. The monthly averages for the twentieth century are based on measurements (they include all days with more than 1.0 mm).

SOURCES: H. Uttinger, "Niederschlag," *Klimatologie der Schweiz*, E (1970), 176–183; Pfister, *Agrarkonjunktur*, Table 6.

exhaustively described in some diaries that a quantification could be made which approximated modern standards observation. 5

A comparison of the averages of meteorological measurements (temperature, rainfall, snowfall, and snowcover) between the late eighteenth and the twentieth century indicates only minor differences. Major contrasts emerge, however, when we compare the extremes: the 228 months of precipitation measurements in Berne from 1760 to 1789 include fourteen extreme values which fall outside the range measured for the same calendar month from 1900 to 1960. These are evenly split between seven months of high rainfall and seven months of drought. Although the data are too few for definite conclusions, they suggest that meteorological stress occurred more frequently during the period covered in the late eighteenth century.

More obvious are the differences in the maximum duration of snowcover. The magnitude of the differences deserves emphasis. Table 3 shows that snow lasted considerably longer in several of the winters in the eighteenth century than it did in the most harsh winter of the twentieth century (1962/63). In the winters of

[5] Pfister. Agrarkonjunktur, 63.

Table 3 Comparison of maximum duration of snowcover in the eighteenth and twentieth centuries at selected places in the Swiss plateau
(Number of days with snowcover during the spring months, March to May, in parentheses.)

WINTER	LOWER PLATEAU	HIGHER PLATEAU
		Gurzelen BE (alt. 591m):
1769/70		126 (45)
	Sutz BE (alt. 463m):	*Berne (alt. 572m):*
1784/85	134 (51)	154 (60)
1788/89	112 (35)	
	Neuchatel (alt. 487m):	
1962/63	59 (--)	86 (12)

SOURCES: Twentieth century: *Annalen der Meteorologischen Zentralanstalt,* IC (1962), 24, 30; *ibid.*, C (1963), 19–20, 25–26; Eighteenth century: Pfister, *Agrarkonjunktur,* Table 15.

1684/5,1715/16, 1730/31,1769/70,1784/85, 1788/89, the orders of differences are sufflciently large that there is little doubt of the accuracy of the conclusion.[6]

The lack of reliable aggregate data on grain output has been a major obstacle to the analysis of the impact of meteorology upon the economy in the prestatistical period. All previous studies are based on fluctuations in grain prices. The underlying assumption that the peaks and troughs of grain prices were closely connected with good and bad harvests has never been verified on a quantitative basis. Grain prices are not merely a function of the current supply. Economic and political variables, such as stocks, speculation, foreign exchange, the output of food other than grain, and governmental measures are intervening variables.7
Although there are no direct measures of annual aggregate grain output, it is possible to estimate such a series for the Re- public of Berne. The governors were required to list in their accounts the yields of tithes paid for every district and to provide

6 Pfister, "Zum Klima des Raumes Zürich im späten 17. und frühen 18. Jahrhundert," *Vierteljahrsschrift der Naturforschenden Gesellschaft Zürich,* CXXII (1977), 447–471.
7 Similarities in the fluctuations of grain prices in Western Europe and Mexico have been analyzed by Enrique Florescano, *Precios del maiz y crisis agricolas en Mexico (1708–1810)* (Mexico, 1969), who also provides an exhaustive bibliography on the subject.

aggregate tithe figures for the whole county. A summation of thc aggregatc rcvcnues for the forty-seven major counties provided an estimated annual average of some 2,800 metric tons of grain for human consumption ovcr thc period 1755 to 1797. According to the percentage paid, which was one tenth in the central and eastern part of the Republic of Berne and one eleventh in the western part, this represents a production of 27,800 metric tons. An attempt to estimate the totaloutput of the whole republic was made by the government from I771 to 1773. The resultant figure suggested that the share of output covered by government tithe collection represented some 57 percent of the country's harvest.

Tithes were influenced by several variables.8 The amount of tithes paid in kind (T) depended on the percentage tithed of the harvest (p), the acreage under cultivation (A), and the yield per acre (Y) .Yields per acre are known to be a function (f) of the quantity and quality of labor input (L), the amount of fcrtilizcr applied (F), and the meterological conditions (W). Thus:

[I] $T = p * A * (f(L,F,W)) \qquad Y = f(L,F,W)$

In addition, we have to take into account that the right to collect tithes from certain areas was sold by auction to so-callcd tithc-farmcrs, who carried out the work of tithe collection for provincial governors and were entitled to keep a small proportion of the revenue for themselves. Thus, we should include a dis- turbance term (U) to allow for the effect ofthe auction, providing:

[2] $T' = T \pm U$

For the period under study, p is known to have been constant. The emotional effects of the auction (U) are not likely to have generated a systematic bias, and can be considered a random variable. In aggregating a large number of tithes, we assume that these effects tend to cancel out.[9]

The yield term Y can be analyzed on the basis ofknowledge drawn from agronomical sciences. It is assumed that yield patterns

8 This issue concerns a variety of European scholars. See Joseph Goy and Emmanuel Le Roy Ladurie (eds.), *Les fluctuations du produit de la dîme. Communications et travaux* (Paris, 1972).

9 In addition, the fields were inspected prior to the harvest by government officials who assessed a minimum price, thus precluding understatement. But bidding was restricted to a small group of wealthy farmers which might have imposed some constraints on the bidding.

over time are affected by a long-term influence rising from changing inputs of labor (L) and fertilizer (F), on one side, and short- time influence, attributed to weather (W), on the other.l0 With regard to the area under cultivation, which is not known, we can assume fluctuations both in the short and in the long run. Long-term expansions of the area devoted to grain may have been due to the clearing of new land. Long-term reduction on land in grain can be explained as the result of the introduction of new crops, such as the potato, and/or the promotion of grass- land. Short-time fluctuations were of two types: one following from the rhythm of the three-field system (which may well cancel out in aggregate figures) , and the other based on responses to changing prices and to the size of the previous harvest.[ll] Thus:

[3] $A = a_l + a_s$

where a_l represents long-term and as short-term factors.

Given these patterns, it seemed reasonable to split up the tithe series using a trend equation of the form:

$T = a + bt + ct^2$ (t = year -1755)

which permits the separation into a systematic (trend) Component and thc rcsidual fluctuations around this trcnd. Thus:

[4] T = Trend + Residuals

According to our previous hypotheses, we may attribute the trend, which will not concern us any longer in this article, to changing inputs of labor (L) and ferti1izer (F), and long-term changes in the inputs of land (a1) .The residuals are thought to be proxies for fluctuations in harvest size (h') which are generated by the impact ofthe weather and yearly adjustments ofthe acreage (as) .Therefore:

[5] Residuals = as * (f(W))= h'

A test ofthe hypothesis, that residual variation was primarily due

to weather patterns during the harvest year, was attempted with the use of cluster analysis. The computer input consisted of a 40 x 40 correlation matrix

10 R. Pfau, Ein Beitrag zur Wetterertragsstatistik von Halm und Hackfrucht (Offenback a. M., 1964).

11 Pfister, Agrarkonjunktur, 131.

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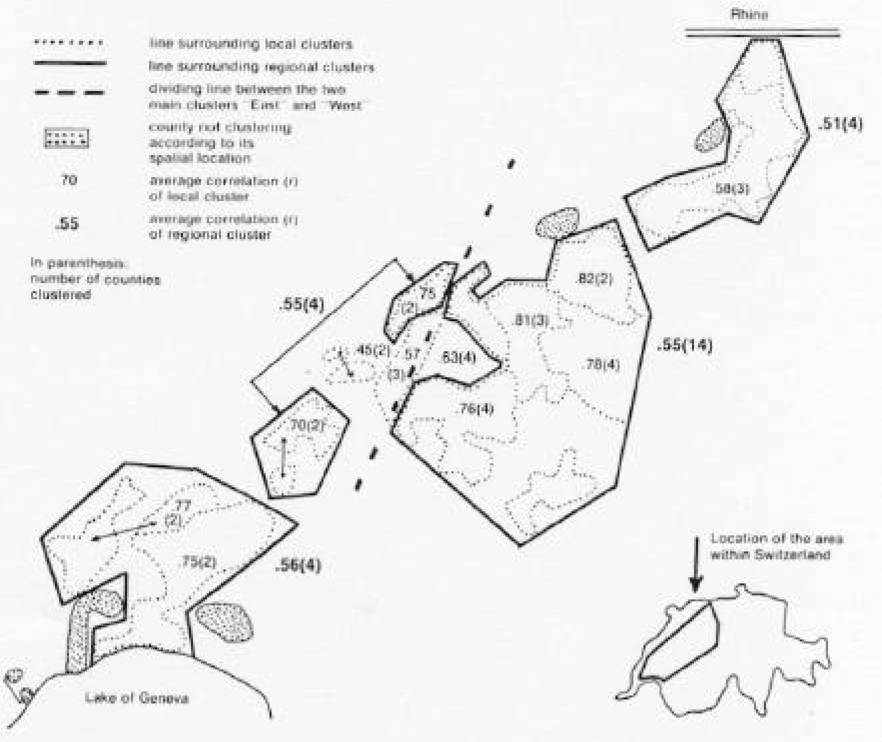
among the residuals of the county tithes, and the clustering was done using the "group average method" available in BMDPlM.12 A cluster consists of a set of counties which has a higher average degree of similarity among its component counties than with any other cluster or variable.

It turned out that most counties clustered according to their spatial location. Figure I shows the mapping of the different clusters. The numbers within the areas indicate the average level of correlation among the counties in the clusters. The number of counties clustered appears in parentheses. The fat line around several clusters surrounds a large cluster. The broken line divides the two major clusters, "East" and "West."

In most cases adjacent counties clustered at the highest level. Adjacent clusters again were most likely to merge into larger

Fig. 1 Spatial Location of Clusters Among Counties According to Tithe Paid 1755–1797



12 W. J. Dixon (ed.), *BMDP. Biomedical Computer Programs* (Berkeley, 1975), 307.

clusters. As the process went on, the outline of major geographical regions emerged. In addition to spatial location, differences in crops seemed to be involved. Wheat and rye were predominant within clusters "West," but spelt was the basic crop within cluster "East." The two main clusters coincided roughly with two regions of different agricultural vocation shown on modern agricultural maps. The kind of clustering observed suggests, there- fore, that the short-term fluctuations in harvests had a strong tendency to follow a spatial pattern.13

How can we interpret the spatial clustering effect? If we consider the size of the yearly fluctuations, the effect of the weather upon crops seems to be dominant. Yields per acre may fluctuate as much as 150-200 percent from one year to the next, whereas it seems improbable that short-term adjustments in land utilized of a similar magnitude could be made within the three field system .14 Weather conditions tend to be similar within areas of considerable size. What varies, however, is the impact of a given weather situation on agriculture. These modifications are due to spatial factors such as soil, altitude, and type of landform on the one hand, and species of crop on the other. A wet season may cause less damage in a hilly area where water runs off than in a plain where the water stands. Whether or not precipitation falls as snow depends on altitude. Further, altitude influences the duration of snowcover and the specific growth stages of a given crop, which accounts for differences in sensitivity to meteorological stress.

The validity of the hypothesis [5] linking changing input to climatic conditions can also be tested by comparisons using ob- served weather. Weather-crop relationships are known to be complex. The study of agricultural science focuses on the analysis of bumper crops and harvest failures in order to investigate the dominant favorable and unfavorable weathersituations.15 An application of this method on the late eighteenth-century tithe-series indicated that the favorable weather patterns were similar to optimal conditions at the present time. In order to analyze the

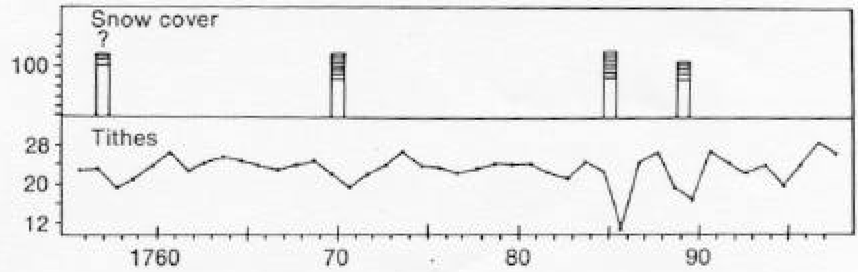
13 Pfister, *Agrarkonjunktur*, Table 27; Philippe Vautier and François Jeanneret, *Klimaeignungskarte der Schweiz fuer die Landwirtschaft* (Berne, 1977).

14 Hans Baumann, *Wetter und Ernteertrag* (Berlin, 1949), 16.

15 Baumann, *Witterungslehre fuer die Landwirtschaft* (Berlin, 1961), 25.

injurious factors, the lowlands and the uplands had to be studied separately.
The aggregate tithe revenues from the Ernmental, a hilly area at altitudes of 2000 to 4000 feet, represent the most typical upland curve. The graphical picture of the weather impact has been simplified by focusing on the most outstanding injurious factor .16 Figure 2 shows striking crop failures in 178 5 and 1789; fewer failures occurred in 1757 and 1770. Output in 1785 for the region as a whole fell56 percent below the trend line. The meteorological side of the picture reveals that this debacle occurred after the longest winter of the previous 220 years, as measured by the duration of snowcover. The harvest failures of 1757, 1770,.-and 1789 seem to be due equally to an excess of snowcover. According to contemporary sources the plants were smothered under the deep snow.
In northern Europe, where deep snow layers are frequent, winter crops are often heavily damaged by smothering due to infection with snow mold (Fusarium Nivale) .Death of the plant is due to carbohydrate exhaustion and the breaking down of the protein substances, a process which favors the development of

Fig. 2 The impact of snowcover on harvests in the higher plateau



Snowcover: Number of days with snowcover on the lower plateau (extremes only).
Dark area: Spring months (March to May).
Scale: days.

Tithes: Aggregate tithes paid to the central authority from the "Emmental" region.
Scale: 10 metric tons.

SOURCE: Pfister, *Agrarkonjunktur*, 184–185.

16 For a detailed analysis see Pfister, *Agrarkonjunktur*, 113–117.

snow mold. Often when ice or snow melts, the subsoil is frozen and, in the absence of surface drainage, the plants may be covered with water for some time. injury may then be due to an excess of water rather than to ice or snow, as such. This would explain why losses in the Swiss uplands were especially heavy when the snowcover remained into the spring months. At this time solar radiation is stronger and stimulates the melting process during the day. In the wheat-growing regions of western Switzerland, heavy rains in the autumn seem to have accounted for most of the bad harvests. According to several observers, the peasants were prevented from ploughing in time; thus substantially smaller areas could be sown. In 1769 the aggregate tithes went down by one third after an amount of rainfall in the preceding September close to the largest measured over the period 1900 to 1960; crop failures under similar conditions occurred in 1778/79 and 1780/81.[17]

I have also examined the relationship between grain prices and tithes. The residuals around the price trend-representing annual variations-were compared with the aggregate tithes for the who1e Bernese state. excluding Argovia (in the northeast) and Vaud (in the southwest) .two regions which were remote from the capital.[18]

It turned out that prices are in many cases, but not always a fair guide to harvest size. Two different types of biases can occur. During dearths, as in 1770 to 1771 and 1793 to 1795, the increase in prices was much larger than the decline in harvest size would have suggested. This finding is consistent with the well known “Labrousse effect,” But an exceptionally poor crop, such as that of 1785, produced only a small price peak.[19]

Table 4 indicates that the exclusion of several aberrant years raises the coefficient of correlation substantially. In some of these years the potato crop was particular1y poor, such as in 1777, 1778, 1793, and 1794. In others, such as in 1785 and 1795, it was probably abundant. This interaction effect between grain prices

17 *Climate and Man*, 327; Titow, "Evidence of Weather," 363.
18 Pfister, *Agrarkonjunktur*, Table 26.
19 C. Ernest Labrousse, *Esquisse du mouvement des prix et des revenus en France au XVIIIe siècle* (Paris, 1932).

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Table 4 Correlation among the residuals of grain prices (spelt) and the harvest size estimated from tithes, Republic of Berne (without Argovia and Vaud) 1755–1797

YEARS EXCLUDED	NUMBER OF OBSERVATIONS	r
—	43	.54*
1770, 1785	41	.61**
1770, 1771, 1785, 1794, 1795	38	.73**
1770, 1771, 1777, 1778, 1785, 1793, 1794, 1795	34	.75**

SIGNIFICANCE: (*) .00030 level; (**) .00001 level.

and potato crops is hardly surprising; a substantial part of the population in the uplands, especially among the lower strata, fed heavily on potatoes. In the years with poor potato crops these people, looking for substitutes, may have increased their demand for grain. But the coincidence of a bad grain harvest with a bumper potato crop might have slowed down the rise in grain prices. Statistical analysis suggests that the influence of the potato crops on grain prices increased over time.20 This may be attributed to the potato boom in the aftermath of the famine of I 770/71, which spread the cultivation 6f the new crop at the expense of gram. .In addition to its astonishing yields-an acre planted in potatoes could provide two to four times as much food value as an acre planted in grain-the American crop was not damaged by wet autumns, long winters, and hailstorms. But potatoes arc known to be susceptible to droughts and long periods of heavy rain during summer, which conditions would not lead to substantial losses of winter grains. Thus, the new crop worked in favor of a better distribution of the weather risk.[21]

In the pre-Alps the population fed mainly on dairy products. We may therefore also look for an interaction between dairy production and grain harvests. In summer most cattle were grazed

20 The computation of Spearman's rho yielded for 1755–1775, .58, for 1776–1796, .45.
21 Langer, "American Foods," 54; W. Brouwer, *Die Beziehungen zwischen Ernte und Witterung in der Landwirtschaft* (Goettingen, 1926), 63.

on the Alpine pastures; the output of cheese rose or fell according to the length and the character of the grazing season, which was in turn determined by the date of Alpine thaw and the frequency and duration of fresh snow layers during summer and early autumn. The supply of hay produced in the plateau was affected by the amount of summer rain, and the demand depended on the weather conditions during winter and particularly on the duration of snowcover in spring. When hay became short, some cattle were fed with substitutes such as straw and branches of pine; others had to be slaughtered. Snowy winters and wet, cold summers were therefore critical weather patterns for Alpine agriculture .22

What were the effects of fluctuations in harvests and prices on demography? At the moment analysis of this issue is limited by the small number of demographic series available for the Swiss countryside. The data in Fig. 3 refer to two parishes in the Valley of Entlebuch, situated southwest of Lucerne, and two parishes in the region of Appcnzell.23

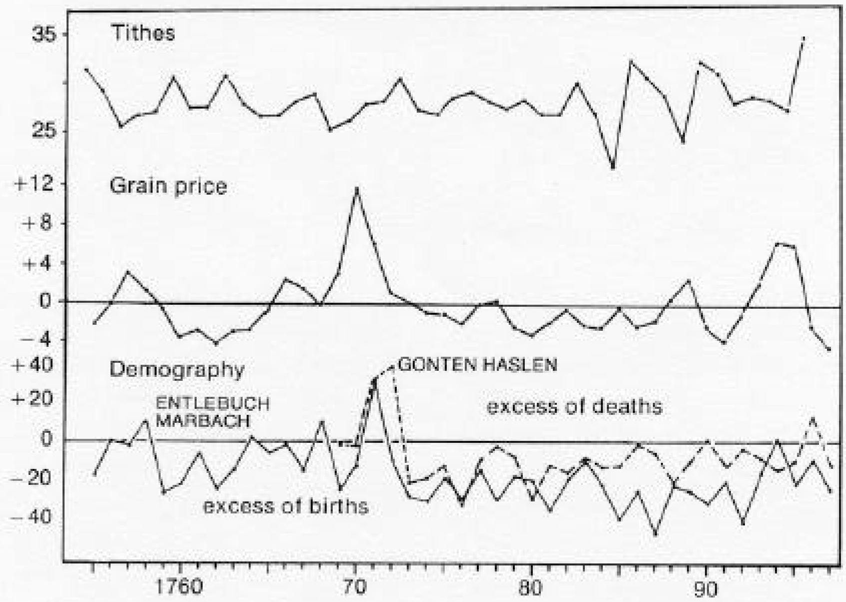
The graph shows the excess of births and deaths. In both series the most remarkable peak of mortality falls in the European crisis of 1770/71 .In Entlebuch minor mortality peaks can be observed in 1758 and 1768. After 1771 there was an obvious shift in favor of an excess of births, thus indicating a steady population growth. In Appenzell mortality was still increasing in 1772, while it was falling rapidly in Entlebuch.

In the grain price curve the trend has been filtered out in order to sharpen the measure of crisis. The correlation with demographic patterns is uneven. Obviously the big peak of mortality coincided with the highest relative level of grain prices in the series. Consumption of indigestible food appeared in various contemporary sources as the most frequent cause of death. In contrast with 1771/72, there was no evidence of a famine during the second price maximum in the 1790S. We find neither a mortality peak nor a marked slump in harvest size. But the example of 1770/71 makes clear that harvest size

22 Juerg Bielmann, *Die Lebensverhaeltnisse im Urnerland waehrend des 18. und zu Beginn des 19. Jahrhunderts* (Basel, 1972); Markus Schuermann, *Bevoelkerung, Wirtschaft und Gesellschaft in Appenzell-Innerrhoden im 18. und fruehen 19. Jahrhundert* (Appenzell, 1974).

23 Silvio Bucher, *Bevoelkerung und Wirtschaft des Amtes Entlebuch im 18. Jahrhundert* (Luzern, 1974); Schuermann, *Appenzell*, 319-325.

Fig. 3 Harvest patterns, grain prices, and demographic fluctuations in late eighteenth-century Switzerland



Tithes: Aggregate tithes paid to the central authority of the Republic of Berne
Scale: 100 metric tons.
SOURCE: Pfister, *Agrarkonjunktur*, Table 25.

Grain price: Average market price for spelt in Berne during harvest years (August–July). The picture shows deviations from the trend (residuals).
Scale: Batzen
SOURCE: Pfister, *Agrarkonjunktur*, Table 28.

Demography: Excess of deaths and births in two parishes in Entlebuch, Lu and Appenzell, AI.
Scale: Persons.
SOURCES: Bucher, *Entlebuch*, 16–17; Schuermann, *Appenzell*, 319–325.

cannot fully account for the appearance of famine. Harvests did fail repeatedly in 1769 and 1770, but the aggregate deficits in 1784 and 17 85 were much larger. The attempt to clarify these contra- dictions may rest on the presumption that a set of regulative forces operated so as to mitigate the effects of harvest debacles.

In addition to bread, the peasants' diet included a variety of foods, such as potatoes, milk, cheese, vegetables, and fruit, which could be used as substitutes for each other. Grain could be sup- plied from governmental stocks and imported from remote areas. This equilibrating effect may account for the situation in the 1790s.

Although there is some evidence of poor potato crops due to drought in 1793 and 1794, the grain harvest was about average and there is no indication of a slump in dairy production. The production levels may have enabled the poorest strata of the population in the countryside to survive because they produced their own food and, in most years, were unconcerned by fluctuations in grain prices. The boom in grain prices may well be explained by the effects of the First Coalition War which swept over Western and Central Europe at that time.

In the case of 1770/71 , however, all of these balancing forces seemed to have failed to operate. Meteorological stress has thus far been analyzed with respect to single crops. This focus, however, must beg the question of overall food resources, since meteorological stress could affect different crops in a somewhat different manner. A simultaneous failure of several crops must be conceived as the result of a cumulative impact of a number of unfavorable weather conditions, and would be more damaging than a failure of just one, even the principal food crop.24

The second aspect which merits attention is the duration of the stress. Successive bad harvests were likely to produce several feedback effects such as the depletion of stocks, the shortage of seed grains, and the slaughtering of cattle. Thus a succession of bad harvests could be expected to have much worse effects than would several isolated episodes over a period of years .

The third aspect to be considered is the impact of weather in other geographical areas: high and low pressure systems, which determine the weather situation, extend over hundreds of miles. Recent studies of circulation patterns reveal that the occurrence of anomalies can coincide even in different parts of the globe .25 When deviations from the normal weather pattern occurred simultaneously in areas as large as a continent, agrarian output may

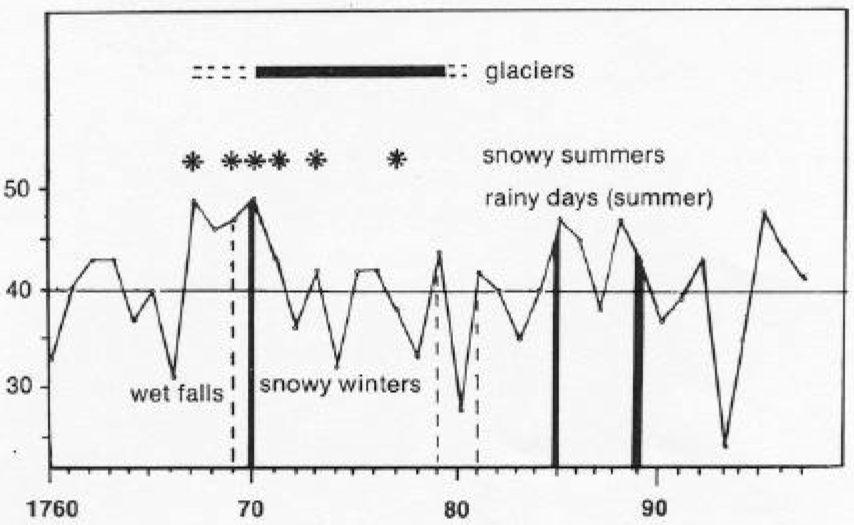
24 Michael Drake, "The Growth of Population in Norway," *Scandinavian Economic History Review*, XIII (1965), 124, gives a similar interpretation.

25 Hermann Flohn und Heribert Fleer, "Climatic Teleconnections with the Equatorial Pacific and the Role of Ocean Atmosphere Coupling," *Atmosphere*, XIII (1975), 96–109.

have been affected in a number of different countries at the same time.

Figure 4 shows the different kinds of meteorological stress discussed in this paper: wet autumns affecting wheat production in the Lowlands; long winters damaging the seeds in the Uplands and depleting the hay stocks; wet summers affecting the output of hay , potatoes, and grain; and snowfalls on the level of Alpine meadows during summer reducing the amount of cheese pro-

Fig. 4 The cumulation of damaging effects during the climatic fluctuation 1767–1771



Legend

Glaciers: Period of main advance.

Snowy Summers: High frequency of fresh snow layers on the Alpine pastures (May 15th till September 15th).

Rainy days: Numbers of rainy days in Basle during the summer months (June till August).
Scale: days. The line marks the mean.

Wet falls: Large quantity of rain during fall.

Snowy winters: Very long duration of snowcover.

SOURCES: Heuberger, *Alpengletscher*, 274; Pfister, *Agrarkonjunktur*, passim; *idem*, "Die Schwankungen des Unteren Grindelwaldgletschers im Vergleich mit historischen Witterungsbeobachtungen und—messungen," *Zeitschrift für Gletscherkunde*, XI (1975), 74–90.

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duced. The graph reveals that the period from 1767 to 1771 stands out by a series of five wet summers. Within this series there is a remarkable cumulation of meteorological stress: the wet autumn of 1768 is followed by a long winter in 1769/70, which in turn precedes the extremely snowy summer of 1771.

The worst impact of this cumulation occurred in the year 1771 .Harvests were poor for the second consecutive year; dairy production was down through the losses of herds, the shortage of the Alpine pastures, and the bad quality of hay. Potatoes for seed were rare and expensive. The grain stocks of the government were empty. Supply from traditional breadbaskets such as Burgundy, Swabia, and Alsace was hindered by embargoes. Throughout Middle and Western Europe grain prices had risen to crisis levels. In the opinion of Adam Smith, this boom "seems to have been the effect of the extraordinary unfavorableness of the seasons. ...The seasons for these ten or twelve years past have been unfavorable through the greater part of Europe. ..." Quick advances of many glaciers within the whole Alpine region and wine harvest dates for France indicate that the exceptionally long series of wet summers involved large areas.26

The overall impact on agrarian production cannot be estimated at the present. Slumps in tithe revenues from Burgundy and Alsace suggest that the traditional suppliers of Switzerland had probably little or no excess to sell; their embargoes seem to have been the result of a general shortage. The series of harvest failures throughout Europe show a regional shift over time. In Central and Western Europe the crisis culminated between 1769 and 1771; Northern Europe was hit hardest in 1771 and 1772. The crisis in Central Europe coincided with a big famine in Bengal, which fo11owed a severe drought for two consecutive years and took the lives of some 3 mi11ion people in 1769/70.27

26 Wilhelm Abel, *Massenarmut und Hungerkrisen im vorindustriellen Deutschland* (Goettingen, 1972), 80; Adam Smith, *An Inquiry into the Nature and the Causes of Nations, I* (London, 1811), 310 ff; Helmuth Heuberger, "Die Alpengletscher im Spaet- und Post-glazial," *Eiszeitalter und Gegenwart*, XIX (1968), 274; Le Roy Ladurie, *Times of Feast*, 60–61, 369.

27 A. Silbert, "La production des céréales à Beaune d'après les dîmes," in Goy and Le Roy Ladurie, *Fluctuations*, 152; Beatrice Veyrassat-Herren, "Dîmes alsaciennes," in Goy and Le Roy Ladurie, *Fluctuations*, 99 ff. An outside reader provided me with a copy of the diary of O. Holmboe in Oslo (1710–1773) which describes the meteorological impact as follows: "1771: Very bad crop . . . At seeding time there was much cold rain, made plowing difficult . . . Much rain at harvest time, hay destroyed, grain crop also partially

A current climatological hypothesis is that the injection of volcanic dust into the atmosphere may be the cause of many short-term climatic fluctuations. During the period in question there is some evidence supporting this hypothesis: during 1766 eruptions of Mayon (Philippines) , Hekla (Iceland) , Etna (Sicily) , Vesuvius (southern Italy), and Iwakiyama Oapal1) were observed. According to an observer in Brandebourg, the sun was frequently veiled by dust during this summer. An exceptional wave of volcanic activity seems therefore to have preceded the climatic fluctuation around 1770. The secular record of snowcover in 1784/85 took place less than two years after the giant outflow of the Laki rift in Iceland, which, in the summer Of1783, had filled the North Atlantic and great parts of Europe with volcanic dust. Large scale climatic instability around 18 161 17 occurred also after the explosion of Mount Tomboro in 1815, which volcanologists tend to consider as the greatest eruption since 1500.28

There are further striking analogies between the situation of the ear1y 1770S and the climatic fluctuation from 1812 to 1817, which was observed all over Europe, in North America, and in some regions of Asia. In Switzer1and these six summers were, without exception, wet and very cold, and the diluvian summer of 1816 was fol1owed by a long and snowy winter. Within a few years the Alpine glaciers grew rapidly, threatening elevated pastures and forests. Agrarian output in Europe as a whole fel1 substantial1y and the population was decimated by famine, especially within the central part of the continent. Again the famine was not just the result of a bad grain harvest; in the Swiss case the summation of damaging effects and the long duration of the meteorological stress struck al1 the staple foods at the same time; again, substitution was impossible and many neighboring markets were closed.29

spoiled. 1772: Bad year. Cold rain in spring . . . rain during harvest." In 1773 peaks in death rates were registered in Norway: Drake, *Norway*, 125. For Sweden: Eli Hekscher, *An Economic History of Sweden* (Cambridge, 1954), 137. Cornelius Walford, *The Famines of the World. Past and Present* (New York, 1970; orig. pub. 1879), 12, 30, 89, 99.

28 H. H. Lamb, "Volcanic dust in the atmosphere," *Philosophical Transactions of the Royal Society of London*, CCLXVI (1970), 425–533; Pfister, *Agrarkonjunktur*, 96, 85–88; Post, "Meteorological History," 320.

29 *Ibid.*, 332; Pfister, "Die Schwankungen des Unteren Grindelwaldgletschers," 84; Post, "Famine, Mortality and Epidemic Disease in the Process of Modernization," *Journal of Economic History*, XXIX (1976), 19.

Although comparisons between weather patterns are difficult to make, the available evidence for Switzerland suggests that climatic fluctuations of this vigor did not occur again after the end of the "Little Ice Age," of the I85Os.

My conclusions are:

1. Meteorological data in the form of measurements and weather diaries have turned out to be abundant, detailed, and reliable .
2. Comparisons between the eighteenth and the. twentieth centuries show that, although average values for temperatures, rainfall, and snow arc more or less the same, very wet and very dry months were probably more frequent in the eighteenth century. In several cases the maxima of snow duration in the eighteenth century were considerably higher than in the last hundred years. Given the sensitivity of crop yields to major deviations from the usual weather pattern, we may assume a higher frequency and rigor of harvest failures than in our century.
3. Estimates for harvest size can be derived from aggregate figures of tithes paid in kind. Statistical analysis has revealed that the short-term fluctuations of tithes in adjacent counties have a high tendency to cluster, and that the larger clusters coincide with the regional grouping of counties. This prevailing spatial influence can be attributed to the impact of weather .
4. Harvest failures could be causally related to certain types of meteorological stress. In the Uplands a long duration of snow- cover seems to have fostered infection with snow mold. The wheat growing areas in the Lowlands were mostly affected by an excess of rain during autumn, preventing peasants from ploughing. In several cases the harvest debacle can be directly attributed to extreme meteorological conditions.
5. Fluctuations in grain prices were not always related to variations in harvest size, as estimated from the tithes. Interaction with potato crops and the cutting off of grain imports from the neighboring breadbaskets of Burgundy, Alsace, and Swabia can account for the inconsistencies to some extent. It seems that the influence of the potato crops on grain prices increased after the potato boom in the crisis of 1770/71.
6. The analysis of demographic data from two regions of pre-Alpine Switzer1and reveals that neither disastrous harvest fail-

ures nor booms in grain prices were certain indicators of high mortality. This suggests that human eco1ogy had reached a remarkable degree of immunity against the effects of a limited meteoro1ogical and economic stress. We may assume an equilibrium which was based on the use of government stocks, imports, and substitution of different kinds of food in the peasants' diet. The subsistence crisis of 1770/71 seems to be due to a particular kind of meteoro1ogical stress in the context of climatic fluctuation stretching over several years and invo1ving large areas.