Corn at Interest: The Extent and Cost of Grain Storage in Medieval England

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The history of storage of grain in the Middle Ages is important for understanding the past and for its contribution to other studies. It is a simple case of a complex problem in dynamic economics. At the interest rates he faced a medieval farmer seldom stored more than two years in a row; at the transport costs he faced he seldom brought grain from radically different climes. A two-period model and a closed economy are simple conditions for the study of the economics of storage, much simpler than conditions seen nowadays. Further, an assumption about the prevalence of storage underlies much of medieval economic history, and is not irrelevant to modern times. Storage was a species of insurance that could substitute for other species, such as (to pick an example quite at random) scattering of one's holdings of land (McCloskey, 1976). Scattered holdings and the desperate fear of famine they signify are common features of the modern as of the medieval countryside. The force of the economist's argument (see, for example, Theodore Schultz, 1964) that such customs are insurance rather than rural idiocy depends on a quantitative measure of at least one alternative. Storage is the easiest to measure.

The history of storage is important, too, for what can be discovered along the way. Most notably, a measure of the cost of storage sheds light on the prevailing rate of interest, illuminating its hitherto obscure history. The reasoning involved, examined in detail below, is that a store of grain is an investment. Wheat put into storage in October and brought out in November must pay over the month the cost of the barn and the guards, the depreciation of the grain, and the opportunity cost of the funds invested. The opportunity cost is the rate of interest. The rate was shockingly high. Stores of grain were therefore very low, and medieval men lived from hand to mouth—as one might have judged as much from their poetry as from their markets. In the sixteenth and seventeenth centuries their desperation relaxed, at the very time that interest rates fell. The last famines in England (Scotland was later) were in the 1590's (Peter Laslett, 1965, ch. 5). From the history of storage, in other words, one can infer that the interest rate had fallen quickly and deeply, an early stirring of modern economic growth.

I. The Direct Evidence that Storage was Small

The history of European storage has been neglected because the materials for its study appear so unpromising. One can learn a little from archaeological studies of grain storage, chiefly what the bins looked like, and a little from pretty tales and folklore. In 1540 at Nuremberg, for instance, Charles V tasted bread made from 118 year-old grain. It was proverbial in the fifteenth century, again, that "Winter alle etes/That summer begetes." Aside from such scraps there is little,

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and the subject has therefore been left to bald assertion and counterassertion. A leading student of the medieval French economy, Georges Duby, asserted flatly in 1962 that medieval Europe "did not know how to store grain or accumulate reserves" (p. 135). A leading student of the medieval Swedish economy, Eli Heckscher, asserted with equal confidence in 1941 that it was on the contrary a "storage economy" (p. 10). Neither provided evidence, nor emphasized the distinction between storage for consumption during the year after the harvest and storage for consumption in later years, the "carryover." The entire crop was, of course, stored for six months on average, because it needed to be eaten, which might justify calling any economy without continuous harvests a storage economy. Yet the carryover could be zero, with no reserves accumulated on the eve of the new harvest. It is carryover that is most to the point. Carryover smooths consumption, provides insurance, and links one year economically to the next.

The direct evidence on the size of the carryover is thin, although what there is suggests that it was small. The evidence must come from those who knew how to write and who wished to write down their doings, the lords and monks and burghers. The so-called "account roll" was an annual report to the lord's auditor by his bailiff combining elements of a balance sheet and an income statement, and in particular reporting fully on the disposition of the year's harvest of grain on the lord's own farm (his "demesne"). Accounts have been published for a dozen or so English estates out of the hundreds that exist in manuscript. The simplest way to use them is to look for the amount of "old grain" on hand at the reporting date, traditionally just after the harvest, and to divide that amount by the crop. The conclusion is that the carryover was small. For example, usable accounts of wheat from 170 of the years from 1208 to 1448 at Crawley, Hampshire contain only nine mentions of old wheat in any guise (N. S. B. Gras, 1930, pp. 339–43: "old," "from the previous year," "remain," "remain in sheaf," "left over"). These nine amount to something under 2 percent of the wheat produced in the 170 years in total.

An apparent difficulty with such evidence is that it is a lack of evidence. The rolls do not always say "old grain:nil." They often say nothing, leaving the observer to make the inference that nothing does mean nil. Yet William Beveridge was willing to make it: "Grain remaining from a previous year does not often occur, and if it does it is noted" (Beveridge, 1927, "Notes on Sources"). And more recent scholars agree: "bailiffs were appearing before auditors who had last year's account at hand. Had any corn been left on last year's account the bailiff would be required to account for what happened to it" (Eleanor Searle).

After a series of exceptionally good years, of course, the carryover might well be substantial. On the estates of the Bishop of Winchester in southern England, the years up to 1223 clearly were good ones. The manor of Wycombe carried over more quarters of grain ($246\frac{7}{8}$) than its entire crop (213), as did Ecchinswell and Burghclere (Beveridge papers, box 32, A49). The other manors carried over less, but a lot. The fifteen manors with usable accounts in 1223 had old grain of 1,561 quarters while harvesting 2,742 quarters, or carryover of fully 57 percent. But the usual case was no carryover at all. In 1220, only six out of seventeen manors had any carryover; in 1225, so soon after the remarkable prosperity of 1223, only four out of more than thirteen did; in 1236 only three out of eighteen. Not every year has usable accounts on the Winchester manors, but those that do most commonly have no single instance of carryover: 1226, 1231, 1232, 1235, 1244, and on into the century, punctuated by occasional bonanzas (such as the year 1256 at the big manor of Taunton: 624 quarters of grain "of the second year" and even 182 "of the third," as against 824 quarters fresh from the fields). The bonanzas were rare, and not to be relied upon.

These, of course, were bonanzas to the rich, not to the average man. One would like to know how if at all the other 95 percent of the population carried over grain from one harvest to the next, but the evidence is even thinner than that for the larger owners of land. Certainly there was no sharing out of what the richer folk might hold. Around 1500, a priest scolded a rich and selfish ploughman (this at Lent, incidentally, long before the next harvest):

> Thou knowest that of corn is great scarceness,
> Whereby many for hunger die, doubtless,
> Because they lack their daily bread—
> Hundreds this year I have seen dead;
> And thou hast great plenty of wheat
> Which men for money now cannot get.
> [Celia Sisam and Kenneth Sisam, p. 516]

The priest proceeds to swindle the ploughman out of his plenty, for the benefit of the poor. But the poet is silent on the size of carryover.

Stefano Fenoaltea (1970) has attempted to use other sources (though still pertaining to the rich) to estimate the carryover, namely, the number and dimensions of monastic barns. He estimated the carryover to be very high, concluding that "the monastic barns alone could hold enough grain to feed England's human population for over a year and a half" (p. 139). His reasoning is in error, for it does not allow for the storage of seed, which was at medieval yields fully a quarter of the crop. The correct arithmetic is as follows. Suppose that the barn's capacity was commonly exhausted.[1] Suppose too that carryover was some fraction, c, of the year's whole consumption (taken to be 3.0 units, with 1.0 for seed, the whole output being 4.0). If the capacity of the barns was as much as 1.5 times annual consumption, the accounting of the crop is

$$\text{Barn Capacity} = \text{Consumption} + \text{Seed} + \text{Carryover}$$

or,

$$(1.5)(3) = 3 + 1 + c3$$

The carryover share c implied by this capacity of one-and-one-half times consumption is 1/6, not 1/2.

Since carryover is calculated here as a residual it is sensitive to small errors, and the errors in estimating capacity are not small (for instance, grain was usually not threshed before being stored, but sometimes was). At a capacity of 1.33 rather than 1.50 times consumption the arithmetic implies there would be no room for carryover at all; at a capacity of 1.66 times consumption the carryover fraction would be .33. That is, the fraction varies from zero to .33 when the capacity estimate varies plus or minus by a mere one-quarter or one-fifth.

The decisive objection to a large carryover, however, is evidence on the frequency of starvation. The distribution of production is known to be normal with a standard deviation of 35 relative to an average of 100; starvation is known to have occurred at a consumption of 50 relative to 100 (McCloskey, pp. 141–45). One can use tables of the normal distribution to reckon the waiting time to starvation, seeing whether large carryovers give reasonable waiting times. For example, if the carryover against crop failure was 10 compared with an average consumption of 100, then a peasant could survive any single year (i.e., consume 50) with a crop of 40 or above. A crop below 40 would cause him to starve, as would two crops in succession of, say, 44 and 44 (since the carryover, depleted by 6, could not be rebuilt before disaster hit again). But large carryovers do not give reasonable waiting times: see Table 1.

The actual waiting time calculated from the Anglo-Saxon Chronicle and other sources is on the order of 10 or 15 years (see McCloskey, p. 144). The 30 to 476 years of waiting time characteristic of high carryovers

[1] The capacity of barns would not in fact have been exhausted, since barns were built for the *maximum maximorum*, the peak harvest year as well as the peak month within a year. Transport costs were high, implying that it would be optimal to overbuild local capacity. Almost never would there be a year using every barn in England to capacity, since each region would not have the same bumper crop. More commonly, down to early modern times in much of Europe, capacity in one region might be fully utilized while it went abegging, literally, in another.

TABLE 1—EXPECTED NUMBER OF YEARS BETWEEN FAMINES FOR VARIOUS CHOICES OF CARRYOVER AND THE FAMINE LINE
(Average consumption = 100)

Famine Line relative to 100	Carryover (Percent)			
	5	10	20	50
50	22	32	44	476
60	13	16	28	28+

are too long, sometimes absurdly long. Even a starvation level of 60 does not easily reconcile high carryovers with the short waits observed. That the medieval economy was haunted by starvation, in short, implies that it had little in its stores of grain.

Particular episodes of famine suggest that carryovers were at most on the order of 5 percent of consumption, not 50 percent, surely, or even 20 percent. The years leading up to the autumn of 1315, when the crop was very poor all over Europe, were not bad. Yet Henry Lucas notes that by the spring of 1316 "the old stocks became completely exhausted" and wheat sold in England for 40 shillings a quarter (compared with 5 shillings in a normal year) (1962, p. 55). He gives a table of deaths in Ypres, rising sharply in the spring. Where was the six-month buffer stock? On the demesnes of the Bishop of Winchester, net yields in the bad years 1315 and 1316 were around 45 percent of the 1314 yield. A buffer stock as large as six months of consumption would have easily permitted consumption in these 2 years at well above the starvation level (50 percent of the average consumption). Yet 1315 and 1316 was burned in men's memories, the worst famine in European history.

II. Using Prices to Show that Storage was Small

The notion of a "storage economy," then, is not favored by the usual evidence, though the usual evidence is scanty. Another class of evidence bearing on the issue, however, is available in large and elastic supply: prices of grain. For no time after the twelfth century is it difficult to get the prices at which manorial farms, monasteries, Oxford colleges, the King's household, chartered towns, and other English institutions bought and sold wheat, barley, oats, and rye. From Poland to Portugal, indeed, medieval records yield prices in limitless array, dated, published, affixed to goods of ascertainable quality, and unused for historical purposes beyond the measurement of long-term inflation. The outmoded yet strangely resilient notion that the Middle Ages were ages of "natural economy" unused to trade, money, and prices looks odd beside such an outpouring. Here in quantities beyond the wildest dreams of intellectual avarice are the statistics of a commercial civilization.

One simple way of using prices is to ask whether the amount they fluctuated from harvest to harvest was consistent with a large and therefore price-damping carryover. They fluctuated a lot, which is inconsistent with it. Annual coefficients of variation calculated from the essentially trendless series of prices of wheat at two manors in Hampshire from 1245 to 1350 for 20-year periods ranged from .20 to .43 (J. Z. Titow, 1969, pp. 97–99). The coefficient of variation in wheat prices at Philadelphia, 1800–25, was .26, and at New York in roughly 20-year periods from 1825 to 1914 ranged from .16 to .34 (U.S. Bureau of the Census, 1975, series E123). The typical fall from medieval to modern times, then, was from about .30 to about .24: a variety of climates newly accessible by cheap transport (the Baltic, for example, in early modern times) was a substitute for a large carryover and had the same effect. The only oddity is that the effect was not even larger.

A further step along the same line of reasoning tests for the influence of carryover by regression methods. If carryovers were unusual, then in a very good year one would expect carryover stocks to be built up, depressing prices in the next crop year below what they would be had the previous crop not been good. One would expect a routine of large carryovers, on the other hand, to allow little impact on prices of a good crop. For a sample of 39 years in the thirteenth and fourteenth century in southern England, one's expectations are fulfilled, if one expected small carryovers:

$$\ln P_t = \underset{(0.28)}{3.59} - \underset{(0.13)}{1.15} \ln Q_t - \underset{(0.11)}{0.205} \ln Q_{t-1} - \underset{(.12)}{0.301} \ln Q^*_{t-1}.$$

The fitted equation (standard errors in parentheses; $R^2 = .76$; Cochrane-Orcutt applied) says that price now (P_t) is reduced very strongly by a high yield now (Q_t), much less strongly (though definitely) by a high yield last year (Q_{t-1}) and strongly by yields last year more than one standard deviation above the mean (Q^*_{t-1}). In other words, last year's yield can be divided into two different variables, yields more and less than one standard deviation above the mean. The equation permits a kink, testing whether unusually high yields lead to unusually high carryovers and unusually great depression of next year's prices. They do. In short, carryovers existed, doubtless. But they were small and sporadic, not sustained at such high levels as 30 or 50 percent of consumption. They were probably closer to 5 percent or less, except after a spectacularly good year.

III. The Cost of Storage was High

The question is, why?—why was carryover so small? The answer is that it was expensive, which fact in its turn buttresses the shaky calculations of its smallness. As has been noted, the cost of storing a bushel of wheat is the cost of the barn per bushel plus the percentage rotting in storage plus the expected percentage loss of capital value due to falls in the price per bushel plus the opportunity cost of the interest forgone on the sum expended on the bushel. In what follows the equation will be broken down into the parts, examining what little direct evidence there is for each. At present it is necessary to accept only that the total carrying cost must be earned in equilibrium. If the storers of grain do not make systematic errors in predicting what prices will be—that is, if they are in the fashionable parlance "rational"—then the price of grain will in fact march up at the monthly carrying cost. It can behave on average no other way. If, on the contrary, storing a bushel for four months from September to January were to earn persistently less than four times the monthly cost (suitably compounded), then storers would store less, driving the September price down and the January price up until the equality was reestablished. The harvest, or the signs of the harvest, break the logic, which begins anew at a price suitable to the size of the new crop. So it goes year upon year, in sawtooth fashion. The slope of the teeth is the cost of storage.

All that is needed is the average slope of prices within the harvest year. The account rolls again are ultimately the chief medieval source. They usually give prices without date ("of wheat sold, whereof 2 quarters the price per quarter 6s. 4d., 44 quarters 4½ bushels the price per quarter 6s 8d" and the like). But sometimes the prices are dated, commonly by saint's days. The largest collection of raw, dated prices is J. E. Thorold Rogers' *The History of Agriculture and Prices in England*, published in 1866, and long recognized as a rich and reliable mine for data. Volume I contains about 170 pages devoted to grain prices in the late thirteenth and fourteenth centuries, or some 27,000 quotations. Some 8 percent of these, about 2,000, have more or less precise dates attached, about fourteen dated quotations on average for each year 1260–1400.

The facts for wheat are most voluminous, because wheat was the commodity of commerce. The monthly rates of change of prices can be calculated from comparisons over various pairs of months. There are 1,075 such pairs observed in the same village and the same year. For instance, one pair is the rise from May to July 1331 in the price of wheat from 6s. 8d. to 6s. 10d. per quarter of 8 bushels in Elham, Kent. There are a total of 22 cases of May to July comparisons in the Rogers data, the first in the crop year beginning in 1272 and the last in 1356, with an average ratio of 1.055 (the standard deviation around the average is high, .160; the standard error is .034). Two-thirds are from Cuxham, Oxfordshire (an Oxford college owned the village); the rest are scattered about southern England. The average

TABLE 2—ENGLISH WHEAT PRICES IN THE THIRTEENTH AND FOURTEENTH CENTURIES, PERCENTAGE RATES OF CHANGE PER MONTH

From	To October	November	December	January	February	March	April	May	June	July	August
September	7.5	8.5	2.8	2.3	1.6	2.0	3.4	4.8	2.0	2.4	1.7
October		3.8	1.4	0.1	0.3	−0.4	1.6	1.6	0.6	3.9	0.6
November			6.4	2.2	1.5	1.2	1.6	0.8	0.7	1.5	1.4
December				6.3	6.8	2.8	2.6	2.6	2.8	0.7	0.9
January					1.9	3.2	4.0	1.4	1.5	0.1	0.8
February						3.7	4.1	4.0	2.4	2.0	2.4
March							3.6	2.2	2.1	2.6	2.8
April								1.2	0	2.8	−0.4
May									1.5	2.7	−1.5
June										4.2	4.0
July											1.5

Source: Authors' calculations, from 1,075 pairs of prices, 1260–1400.

TABLE 3—UNWEIGHTED AVERAGES BY MONTH OF ALL RATES OF CHANGE OF WHEAT PRICES, 1260–1400, ENCOMPASSING A PARTICULAR PAIR OF SUCCESSIVE MONTHS

September-October	3.55	January-February	1.91	May-June	1.52
October-November	2.25	February-March	2.04	June-July	1.78
November-December	1.85	March-April	2.12	July-August	1.29
December-January	2.03	April-May	1.78		

Source: See Table 2.

monthly rate of change of prices from May through June to July was therefore the solution, r, of $e^{2r} = 1.055$, or $r = 2.70$ percent per month, some 38 percent per year.

One way of displaying the results is in a matrix of pairs of months, as in Table 2. One way of summarizing the 66 averages is to say that their average in turn is 2.37 percent per month (32 percent per year), though with a high standard deviation (1.87 percent, a coefficient of variation of .79 around the average) and high standard error (0.23).

Another way to summarize the averages is to extract all the information in the matrix concerning a rate of change between a particular pair of consecutive months, to detect any pattern of seasons. The entries relevant to the March-April comparison, for instance, are all those northeast of the March-April entry, 3.6. Adding them together without weighting double-counts many times over and gives the same weight to an entry such as November-August, which merely passes through the March-April comparison, as to one such as March-May, which is closer to the nub of the issue. Without theoretical light it is hard to see the merit of one average over another. For what this one is worth, the result is given in Table 3. The storage costs are high at the outset, falling to around 2 percent per month (about 30 percent a year). That the cost is lower in the spring probably reflects the arrival of definite news about the next harvest. The lowering may indicate the size of the risk premium required earlier in the year, when news is scant and long-term averages are the only guide to how prices will change.

Averages by length of the gap between months, reported in Table 4, seem also to be telling. What exactly they tell is not altogether clear. Very likely the fall as the comparisons get longer reflects the fixed cost of putting grain in storage. Possibly, too, it represents a selection bias in the evidence, since a more rapid rise in prices over a short period would cause more transactions to be undertaken by the manors and other institutions involved, and a greater likelihood that a pair of prices would fall in successive

TABLE 4—AVERAGES BY LENGTH OF GAP BETWEEN MONTHS COMPARED

Number of Months Gap[a]	Monthly Rate of change[b]	Number of Observations	
		Actual	Expected
1	3.77	254	179
2	3.57	204	163
3	2.06	166	146
4	1.58	138	130
5	1.21	99	114
6	1.61	69	98
7	1.51	64	81
8	2.06	44	65
9	2.47	20	49
10	1.55	13	32
11	1.73	4	16

Source: Authors' calculations of wheat prices.
[a]For example, January–June = 5.
[b]Shown in percent.

months. The form of the matrix of comparisons implies the last column, the expected number of observations at each number of months gap. For example, the 11 elements on the diagonal are one-month gaps, 11 out of 66 total. That is, 11/66 of the 1,075 observations, or 179, should be one-month comparisons under the null hypothesis of equiprobability of each element. There is a marked overrepresentation of brief gaps (close to the diagonal). One could examine the runs of prices that are producing the brief gaps to see if it is plausible that they are themselves a consequence of rapid price rises. In any event, the nature of the sampling biases in the Rogers data are worth pursuing: weighted by the number of observations the average rise is a 2.55 percent per month (35 percent a year), while the average for pairs more than two months apart is only 1.75 percent (only 23 percent per year).

The tentative conclusion from even these crude methods is nonetheless plain. The whole cost of wheat storage was from about 2 to 3 percent per month, or from 27 to 43 percent per year, closer perhaps to 30 than to 40 percent.

The result is confirmed by a more elegant if less rich method, namely, a regression of prices from the same harvest year and place against the distance of days between them. It comes in two forms, depending on the placing of the constant term. Either

$$P_t = P_0 e^{rt} + c' \quad \text{or} \quad P_t = P_0 e^{c+rt}$$

In other words, the price on the second date (P_t) is raised either by a constant cost per bushel of putting wheat in storage (c') or by a constant cost per shilling value (c). The method of estimation of the two forms is different, but their results do not differ radically in the central parameter, r, the rate of growth of prices (here, per day). The cost-per-bushel form required a nonlinear method, giving

$$P_t = P_0 \exp(.001165t).$$

The rate of change is 0.1165 percent per day, or $(1.001165)^{365} = 1.53$, or 53 percent per year. The constant-per-shilling form required logarithms and fitting by least squares, giving

$$\ln(P_t/P_0) = .0082 + .00083t.$$

The R^2 is very low (.07), unsurprisingly so. The standard error of the coefficient on t (that is, time in days) is one-half the value of the coefficient. The implied rate of change is 365(.00083) = .30, or 30 percent a year. The econometrics echoes the ambiguity of the earlier calculations: the cost of storage is probably around or above 30 percent a year, but where exactly around or above depends on exactly how one wishes to look at the facts.

The regression results are based on 61 observations (as against 1,075 in the monthly statistics), about one-half of the exploitable pairs of dated prices in the same location and year. Little would be gained that is not captured in the monthly averages by adding observations dated simply "March" or "Spring." Were they nonetheless added, a definite downward bias from errors in variables would follow (although it is clearly no trick to estimate the error variance from saying "March" when some definite date in March is meant). Four observations of extreme drops rather than rises in prices were junked as outliers: including them turns the

TABLE 5—AVERAGE RATES OF MONTHLY GROWTH IN PRICE FOR MINOR GRAINS[a]

	Percent Rate of Change[b]	Standard Deviation	Number of Pairs of Months with Data[c]	Definition or Use
Rye	4.17 (1.31)	6.16	22	A bread grain inferior to wheat; black bread
Mixtil or Maslin	3.26 (1.36)	6.64	24	Rye and wheat sown together
Drage or Dredge	4.64 (1.51)	7.38	24	Oats and barley sown together
Malt	5.8 (2.1)	3.7	3	Sprouted barley
Drage Malt	1.		1	
Beans	2.5 (3.3)	8.8	7	Pod-bearing vines
Vetches	8.3 (3.1)	7.5	6	Mainly for animal feed
Peas	3.8 (5.)	16.	10	

Source: Authors' calculations.

[a]Thirteenth and fourteenth centuries, September through June only; excluding the famine years 1315–16.

[b]Standard errors are shown in parentheses.

[c]Except for rye, nearly equal to all the quotations.

equations into rubbish, in that the standard errors shoot up and the cost of storage becomes negative. Finally, the procedure truncated the year at 240 days after the harvest was finished (notionally, September 1), because including May, June, July, and August adds, again, more noise than music. The fact is itself significant, helping to confirm the model being used. From May onward, it would become increasingly clear how large the harvest was in fact going to be, causing prices to fan out to their ultimate destinations. No longer would the average experience of past years govern the rate of rise of prices.

Wheat was not the only grain. Barley, for example, was grown to the same or greater extent as wheat (the word "barn" derives in Anglo-Saxon from "barley"). It was used commonly for bread, occasionally for animal feed, or malted and brewed into the quantities of weak beer that made up a large part of the medieval diet. The analysis of barley gives evidence of very large price rises. The one-month comparisons beginning in September, October, November, and June, for example, average a 10 percent rise per month. The minor grains—minor at least as marketed goods—tell a similar story. A rise in round figures of 4.0 percent per month for the minor grains appears reasonable, that is, 60 percent per year.

The results for oats (usually a bread grain) are more full, and tend to the same conclusion that the rise was very high. The average of the 42 monthly comparisons (namely, all except those ending in July and August, when the harvest began, and three months with no information) is a 5.77 percent monthly rate of rise, with a standard deviation of 4.52 and a standard error of the mean of 0.70. A 95 percent confidence interval for oats would run from 3.1 percent to 5.9 percent per month (from 45 to 99 percent per year).

That other grains have so much higher costs of storage than wheat requires explanation. It is possible that lesser grains did not store as well as wheat, or that the dealers in wheat were better placed in the capital market. The cost of storage, in other words, might actually have been higher. But there is a simpler explanation. Because the other grains had to compete with wheat for storage space, and because the space was paid for by the price rise, the absolute price rise per bushel for the other grains would have to have been the same for wheat. Wheat sold for twice as much per bushel as did other grains. In percentage terms, consequently, the monthly rise would have to be higher for the lower priced grains. And wheat stored more compactly than barley. In any event, the annual cost of storage of grain was at least 30 percent per year, and could well have been higher.

IV. The Cost was High Because the Interest Rate was High

The cost of storage fell in modern times. One can duplicate the calculations for the sixteenth century and after, the data being of course plentiful. In the Oxford town market, for example, there are monthly figures from 1618 to 1644. November was the low month for wheat prices, August the high, with a rise between them of only 8.4 percent (the standard error is 3.7), or only 0.9 percent per month and 11.3 percent per year. In Namur, Belgium, 1614–92, the August to June rise for wheat is 12 percent, or only 14 percent a year. In Diest, in the Brabant province of Belgium, the rates of annual rise by crop, 1718–36, are wheat 10.9 percent, barley 14.8, rye 14.5, oats 15.4, and buckwheat 18.1. The instances could be multiplied indefinitely, with the same outcome. The cost of storage, plainly, was much lower in the seventeenth and eighteenth centuries than it had been four centuries earlier.

To explain why it fell, one must turn to the components of the cost—the percent spoilage, the barn costs, and, above all, the prevailing rate of interest. Direct scrutiny of these confirms the impression of very high costs in the Middle Ages and suggests why storage eventually became cheap.

What, then, accounts for the 30 percent cost per year or more? The rotting of grain was probably not more than 10 percent per year. This at any rate is the figure suggested by the scraps of evidence nowadays on poor countries, whose techniques of storage are little better than medieval. The latest estimate comes from a study in 1978 by the National Academy of Sciences:

> Experts involved in the preparation of this report resisted extrapolating post-harvest loss estimates to national or global levels because general estimates cannot be supported with statistically significant data. For planning purposes, however, 10 percent is cited as an average minimum overall loss figure for cereal grains and legumens. [p. 8]

The figure is the loss from harvest to consumption, implying that it would be on average the cost for one-half year (half a year being the average time a bushel of wheat spends in storage if there is one crop a year). The annual cost, which is what is relevant here, would therefore be higher. And the 10 percent is an "average *minimum*" itself, implying again that the average average is higher. On the other hand, these are losses for tropical countries. They would be smaller in temperate countries—and indeed the same report gives 10 percent as an average (not a minimum) for Rhodesia, ranging up to 52 percent on occasion in hotter places such as India (p. 85).

No changes occurred in the character and cost of barns that would explain the fall in total costs from medieval to early modern times. Even in the sixteenth and early seventeenth centuries, Peter Bowden argues, "adequate storage facilities...were lacking," by which he means "adequate" facilities of modern type (1967, p. 816). M. W. Barley emphasizes a continuity of rural building types extending well into the late sixteenth century. It was houses, not barns, that evinced the prosperity of Elizabethan landlords. Writing of rich yeomen in East Anglia even in the early seventeenth century, he asserts that "while many such men enlarged or modernized their medieval houses, the barns they inherited were often perfectly adequate" (1967, p. 744). In the open field areas of the Midlands and the North, there were still in the seventeenth century "hovels" or "helms" or "belfries," that is, granaries on posts with adjustable roofs: but they had been "a regular feature of Germanic villages in the migration period and later; the adjustable roof is shown in manuscripts of the later Middle Ages" (Barley, p. 744). The timber (and labor) with which one might make a barn fell in price relative to grain by about 50 percent from 1450 to 1650 (Bowden's figures, p. 862), but it would be surprising if the barn costs—except perhaps on account of the high interest rate on the investment in structure—were much of a factor in storage costs to begin with.

The direct testimony on the rate of interest in the Middle Ages is not easy to interpret. The traditional usury limit in England for what amounted to pawnshop loans on good security was 2 pence per pound per week, or $43\frac{1}{2}$ percent per year at simple interest and 54 percent compounded. The figure is reproduced in all discussions of medieval interest rates. So too is the history of the law of usury and its evasion. The prohibition of usury was irrelevant: that the sin of taking interest should be committed frequently is no more surprising than that the sin of adultery was. Interest rates far above 50 or 100 percent were common on personal loans, though the rates on commercial loans among the rich were at more modern levels. It is this division of the market that makes the evidence cloudy. In poor countries, seven centuries later very high interest rates by moneylenders coexisted with subsidized loans at 5 or 10 percent from government agencies (U Tun Wai, 1956, 1957). What seems clear about the European experience is that, at least in the portion of the market in which ordinary peasant cultivators found themselves, the early modern period witnessed a great fall of interest rates. By the late seventeenth century in Lincolnshire, for example, probate inventories attest that "nearly everyone with surplus cash appears to have let out at interest," at only $4\frac{1}{2}$ to 6 percent per year, when rates in London were 5 percent (B. A. Holderness, 1975, pp. 108, 97). At the *haute finance* end of the scale, there is a halving of the interest rate in Northern Europe from the thirteenth to sixteenth centuries, although the clarity of the fact is muddied by the vagaries of war and the varieties of financial instruments (Sidney Homer, 1977, p. 142).

The evidence from grain prices is in important senses better than that on financial instruments. It is uniform over many centuries. It is available for all parts of Europe. And it is free of default: one cannot default on one's own investment in stored grain, or in whatever investment alternative to stored grain was the opportunity cost of investing in grain. Such an investment is not, of course, free of risk, for stored grain faces its own hazards. One was taxes, which were assessed (usually in the fall) on any asset the taxgatherer could spot. Another was the risk of a fall in prices, since prices did not march up mechanically. More subtle calculation might extract the premium for the price risk from the data, though such subtleties are hard to take seriously. The variability of grain prices, as was noted earlier, did fall a little, though hardly enough to account for a revolution in the risk premium demanded. A measure of its size would have other uses, in suggesting how medieval people viewed the hazards of life more generally. No matter: even the pure interest rate in the Middle Ages will be found to have been very high.

V. Other Assets, such as Livestock, Reveal a High and Falling Interest Rate

The pricing of any asset embodies the interest rate. Statistics on livestock, for intance, are rich sources of indirect evidence, supporting the conclusion that the medieval interest rate was high and fell sharply by the sixteenth century. The statistics have survived because livestock were worth keeping records on—easy to steal, often put in the care of others, and frequently bought and sold. The data include herd and flock size and composition by sex and age, death rates, slaughter rates, and prices of inputs and outputs (hay, grazing land, straw; labor; milk, cheese, butter; wool, hides). All manner of ratios among these things are governed by the prevailing rate of interest, and can be forced to tell what it was.

One ratio, for example, is of net revenues to the value of the capital invested in animals. It is, of course, the interest rate. On the Crawley, Hampshire estate of the Bishop of Winchester in 26 years, with the requisite facts from 1208–09 to 1254–55, the typical yearly stock of sheep was worth about £56 (on the order of 22 man-years worth). The earnings attributable to the sheep on average each year were £4.2 from animal sales, £14 from wool, £1.5 from pelts, and £5.5 from sheep's cheese, or £25.2 in total. Since Crawley was a market-oriented place devoted largely to sheep raising, it is unlikely that much product was kept unsold for home use. The flock grew its own replacements, which sidesteps the problem of depreciation. The one significant hole in the calculation is the yearly cost of keeping the animals. Sheep are the best case if one is forced to guess, because unlike cattle they do not require intense husbandry animal-by-animal and, unlike horses, they do not (except lambs) require feed grain. The interest rate on this reckoning is 45 percent (or a little under if allowance is made for labor, grazing, and fencing costs).

A calculation that skirts the difficulty of knowing costs of upkeep asks how much interest rates fell. The claim is that the sixteenth century witnessed a great fall in interest rates. Bowden's indexes of prices of sheepish things (see p. 848ff) rise during the great inflation of the Long Sixteenth Century from 1450–99 (= 100) to 1640–49 thus: sheep themselves, the capital good, to 681; the revenues from using the capital good, wool and sheepskins, to 396 and 372; the costs of using it, hay and straw, to 768 and 612. Note that revenue fell relative to costs. Consider that the interest earnings on an investment in one sheep are equal to annual revenue minus cost of upkeep: $iP = R - C$. By advanced algebra it follows that $i = R/P - C/P$. The change in interest, i, must equal the change of the ratios on the right. Wool and sheepskins are revenue, and fall to one-half their former value relative to the price of sheep. Hay and straw are costs, and stay the same relative to sheep (never mind labor, which falls even sharper than wool but is not a large input). If C were known, as is R and P, there would be no trick to finding i. It is not. But knowing the terminal i and the initial R is enough. Suppose (as would be easy to show) that, by 1640–49, the interest rate was, say, 15 percent on such an investment as one sheep. Take the price of that sheep to be the numeraire (thus its price is always 1.00), take the annual revenues before the fall in interest rates to be .45 relative to the price of 1.00 (recall that this was in fact the early thirteenth century ratio at Crawley), and take the fall in revenues to be a fall to one-half this level (as the price indexes imply). Thus in 1640–49, after the fall,

$$.15 = .225/1.0 - C/1.0,$$

where the .225 is half of the original .45. The value of C after the sixteenth century must be .075. The price indexes imply that it did not change relative to the price of sheep. Before the fall of relative revenues, then, the interest earnings were $2(.225) - .075 = 37.5$ percent, as against 15 percent after. The interest rate, as usual, is well above 30 percent.

This conjuring trick would warrant no great confidence standing alone. It does, however, serve to confirm the high net interest found by other methods (and, incidentally, the low costs of upkeep C per sheep relative to the medieval values of R). A more sturdy statistic, and another variation on the theme that cattle are capital more than merely etymologically, is the ratio of the hire rate to the price. A milk cow, in particular, sold for 10 shillings or so in the thirteenth and fourteenth centuries, while renting on various terms for anything from 4 to $6\frac{2}{3}$ shillings (Rogers, 1866, pp. 361, 397; 1884, p. 94, and Dorothea Oschinsky, p. 427). Roughly speaking, the figures imply interest rates from 40 to 67 percent per year. But dividing rent by price is too crude. For one thing, the owner paid for the feed (see Rogers, p. 94), so as usual the calculation runs afoul of the cost of upkeep. For another, cows were not immortal. The second point can be handled by cutting off the stream of discounted returns at the 4- or 5-year average working life of a cow. The price-rental ratio for an asset with a life of n years at an interest rate of i is $(1/i)[1 - 1/(1+i)^n]$. A price-rental ratio of 2 (price of 10s. and rental of 5s., not allowing for deductions for feed) and a life of 4 years implies an interest rate of 35 percent.

Other approaches are possible, though not pursued here. Calves grow up to be "hoggasters" and *bovetti* (heifers), and thence cows and oxen: the project of letting them grow must earn the rate of interest. The death of mature cattle and sheep is not usually an accident (though it should be remembered that cattle were raised chiefly to pull plows, not to fill plates): the optimal slaughter date also depends on the rate of interest. Plowteams were rented: the rental-price ratio reflects the rate of interest. Land itself was both rented and sold: being a perpetuity, the rental-price ratio is the rate of interest. (By the seventeenth century, in France land often rented for 5 percent of its sale price.) It is to be expected that all these will show a remarkably high interest rate in the thirteenth century and a low rate by the sixteenth century.

VI. The Significance of High Medieval Interest Rates

The hero—or villain—of the tale, in short, is the rate of interest. A fall of interest rates from, say, something over 20 percent to something under 10 or 12 percent must have been significant for the history of Europe and for the onset of modern economic growth. An economist can easily believe this. But it is unclear exactly how it was significant. If interest rates were so high, why were Europeans so poor? A few years of moderate abstention from consumption invested at over 20 percent would make a man rich. True, men of all sorts, bond and free, did in fact scale the social ladder quickly in the Middle Ages. The economy and society are known now to have been much more fluid than was once thought. But the point is that the whole society could and would have done so. Perhaps as is commonly argued nowadays in poor countries the menu of opportunities dropped off sharply in quality after the first few items. Low savings rates might explain it, too, though the lack of savings in medieval times is easy to misapprehend. Peasants worked hard at ploughing fallow land and cleaning ditches in aid of yields quite far removed, and this was saving. Since the yield to seed ratios in the Middle Ages was only 4 or so grains returned from each planted, a quarter of the yield had to go back into the ground as investment in seed. On both counts (food being most of income), the saving entailed by medieval agriculture was enormous, albeit brief and direct. Medieval people saved a lot.

A more conclusive line of argument among several possible is that high interest rates made it difficult for peasants to depend on the capital market at all. The reasoning is that loans would be sought before the harvest and paid back after. In the meantime the price of grain would fall, by some 30 percent in a normal year, and much more after the very years of dearth in which most loans would be made. Money that bought little grain before the harvest would have to be earned back by the borrower after the harvest by selling the grain just grown at prices that bought little money. John Waryn of Oxford borrowing 10 shilling on February 1, 1322 to buy 8 bushels of rye might pay back the debt six months later at a monthly rate of 2 percent in money, the rate earned on stored grain. But the price of rye per bushel might have fallen after the harvest from 10 shillings to 7 shillings for 8 bushels. In fact it usually did. To pay back the $10\ (1.02)^6 = 11.26$ shillings on August 1, he would have to have given up $11.26\ (8/7) = 12.87$ bushels of his new crop. For the 8 bushels on January 1, he would pay 12.87 bushels on July 1. The monthly interest rate is not the monetary 2 percent (27 percent per year) but 8.2 percent a month, an unpayable 260 percent per year. If the price fall after the harvest were smaller, say the 12 percent that becomes typical in early modern times, then the real interest rate is 56 percent per year, no small rate but at least potentially payable. The effect of improved storage (itself an effect of the fall in money interest rates) was to cut radically the commodity rate of interest. Before the cut, the peasant was forced back on expensive methods of self-insurance such as scattering of strips in order to avoid having to borrow. All manner of medieval institution—even serfdom itself—can be viewed as replacements for an expensive capital market. Loans among peasants were by no means unknown in medieval times, especially late medieval times (Elaine Clark, 1981). But, by the sixteenth century, they were common, the custom of scattering strips was beginning its long decline, and other medieval institutions were being cleared away.

There is one more point about the relations of medieval villagers revealed by their interest rates. If interest rates in terms of money were at the levels reported here, and higher in terms of bread, the brotherly image of the medieval countryside once taught in school and still taught in Hollywood becomes cloudy. Where is Jack's brother peasant when Jack must borrow from the moneylender at 27 percent in money and well over 100 percent in real terms to survive? The point is one more among many against the myth of the medieval community, that charming product of nineteenth-century German scholarship and speculation on the Middle Ages. The myth of the *Markgenosse*, a putative community of free Germanic citizens, and all that is alleged to follow from it has been under attack for three-quarters of a century. By now most medievalists agree with David Herlihy that "research has all but wiped from the ledgers the supposed gulf, once considered fundamental, between a medieval manorial economy and the capitalism of the modern period" (1971, pp. 154–55). So too the supposed gulf in attitudes towards one's neighbors. "You know, Ernest, the very poor in the Middle Ages were different from you and me." "Yes, Scotty, they were poorer," because of the interest on corn.

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