and productivity change on which the demand theory of British failure rests is poor: capital accumulation was low in the 'eighties, for example, yet productivity growth was rapid.

A measure of productivity growth using national aggregates of output, labour, and capital, however, is a fragile foundation on which to erect theories of British success or failure. This is not because of the large size of the uncertainties in the data, although those compound the problem. The difficulty is that even with very good data the range of doubt in the result is large. This is a general problem and applies to the measure of productivity change used here as well as to the conceptually less complete measures used elsewhere. For example, the measure of productivity grew at 1·2 per cent per year from 1870 to 1900, a respectable pace. If the estimates in 1870 and 1900 of real gross national product, the stock of capital, the labour force, and the shares of capital and labour in national product are incorrect by as little as ±3 per cent, however, the resulting estimate of productivity change will range from 0·77 per cent per year to 1·62 per cent, that is, by comparison with the United States, from failure to success.

The case for failure or success in the growth of productivity must rest ultimately on international comparisons of productivity in specific industries, not on the aggregate measures about which the controversy on British economic performance has hitherto revolved. The measure for each industry, of course, will be open to the same criticism, but if the errors for each industry are independent a set of many industry studies will constitute a sample of British behaviour from which more reliable inferences can be drawn. For the present, it is enough to show that the aggregate measures are consistent with success.

IV

It is implausible, then, to draw the lines of causation in late Victorian England from export demand to the output of the economy. The thesis expressed here is that the resources available to the economy were not elastic in supply and reallocation of them (capital abroad, for example) would have brought little or no additional growth. The growth of output depended on how productively the available resources were used. The measure of productivity suggests no great failure of Britain on this score. There was a dip of productivity in the 1900's, but it was too short, too late, and too uncertain to justify the dramatic description "climacteric". Nor does it support the notion that British businessmen were marking time from the 'seventies onward.[1] There is, indeed, little left of the dismal picture of British failure painted by historians. The alternative is a picture of an economy not stagnating but growing as rapidly as permitted by the growth of its resources and the effective exploitation of the available technology.

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[1] D. Landes, for example, asserts that "There is no doubt, that British industry was not so vigorous and adaptable from the 1870's on as it could have been."—Op. cit. p. 559.

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ENGLISH OPEN FIELDS AS BEHAVIOR TOWARDS RISK

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THE HISTORIOGRAPHY OF RISK

In much of England, from the earliest times to the nineteenth century, peasants held their land in many little scattered plots. Any description in the present state of knowledge is uncertain, but it is probably close to the mark to say that the typical villager in the Midlands of England, before the enclosures of the seventeenth and eighteenth centuries, held some 20 acres in the fields of his village in twenty or so separate locations. This is a most peculiar way to hold land, or at any rate so it has seemed to most observers of the system since the first enthusiasm for enclosure in the sixteenth century, because it appears to reduce output, a strange burden for a community near starvation to assume. The most obvious loss is the time spent wandering from plot to plot, but there are others of more consequence documented in some detail in the paper of which this is a continuation: the externalities of having close neighbors were high, the cost of fencing (and therefore of raising animals in private) high as well, and the system required the village to impose a clumsy common routine on all its members (McCloskey, 1975a). Although the output lost, by comparison with more consolidated holdings, was not as high as one might suppose from the intemperate language of improving pamphleteers, neither was it trivial. I have elsewhere used the typical increase in the rent of land after enclosure to estimate that the proportion of a village's output lost in the

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seventeenth and eighteenth centuries was on the order of 13 percent (McCloskey, 1975b). In the centuries of full vigor of the open fields the output lost was no doubt lower, perhaps 10 percent. Yet why would a malnourished peasant throw away a tenth of his output?

Historians of medieval agriculture have for the most part answered this question in an off-hand way. It appears that the sharing of plow-teams, a spirit of egalitarianism, or the operation of inheritance laws, all of which have at one time or another held the field, fail to explain scattering. The one explanation that shows promise is that plots were scattered to insure against disaster.

The argument is that within a single English village there was enough variability in the yield of land in different locations and under different crops to make it desirable to hold a diversified portfolio of plots. The land and weather of England is notoriously variable, even over the two miles square or so of the typical village. A place with sandy soil on a rise would shed excessive rain while one with clay soil in a valley would hold insufficient rain; a place open to the wind would grow wheat likely to lodge if there were high winds and rain at harvest time but free of mold in a generally wet year, while a sheltered one would be relatively immune from windy disasters but less dry and more moldy on that account; and one place could be hit by flooding, insects, birds, rust, rabbits, moles, hail, hunting parties, thieves and wandering armies, to name a few more of the reasons an English peasant would want insurance, while another close by would go free. A year of high prices for wheat might be a year of low prices for barley and oats, adding a price risk to the yield risk. When whole areas of a village were set aside for each crop, a natural result of scattering of holdings from other causes, the price risk would induce the peasant to hold land in all fields, for a man wanted bread, beer and feed for his animals regardless of the weather and would be averse to the risk of facing high prices he would assume were he to specialize in one crop and one crop area.

Further, before the seventeenth century risks were higher and the opportunities to avoid them more limited than they were to become later. The miserably low ratio of yield to seed before the agricultural revolution meant that a given percentage variation in the total crop was reflected in a larger percentage variation in the consumable crop, after allowing for seed. The techniques of drainage that have to some degree brought the effects of wet weather under control were unknown or expensive. High costs of transportation reduced the variety of weather represented in a given agricultural market and therefore raised the variability of prices above what it was to become in modern times. Futures markets for grain were rare. The market in loans to tide over a bad year was poorly developed. And if the peasant's wealth was not exclusively his seed and standing crop, the other assets he might have, from cattle to gold, were themselves subject to the high risks of natural disaster and random taxation. The inefficiencies of the open fields, in short, were payments on an insurance premium in a milieu in which agricultural yields were

low and unpredictable and in which the costs of a shortfall—at best crushing debt or malnutrition and its associated diseases, at worst starvation—were high.

Risk aversion as a motive for scattering plots figures sometimes in studies of medieval, still more of modern, peasant agriculture. Although he did not, on this point, marshal the evidence, and leaned towards an explanation of scattering based on communal solidarity, Marc Bloch is exceptional among historians in emphasizing the force of risk aversion. The schemes for consolidation encouraged by French governments in the eighteenth century, he argued, were frustrated not only by the conservative and distrustful attitude of the peasants, but also by their concern "to reduce exposure to agrarian accidents . . . to a minimum by working plots scattered over the whole terrain." If the wheeled plow in the regions of heavy soils could explain the great length of plots, risk aversion could explain their narrowness and great number, even when light plows were used: "If the plots were dispersed . . . everyone had some hope of avoiding the full impact of natural or human disasters—hailstorms, plant diseases, devastation—which might descend upon a place without destroying it completely." (Bloch, 1966 [1931], pp. 233, 55.)

One must look outside the remote European past for much more testimony on the point. Scattering is a common feature of all manner of peasant agricultures, from Japanese paddies to Swiss meadows. Economists, government planners and the representatives of international agencies have generally viewed it as a valueless result of egalitarian inheritance systems, of irrational attachments to particular parcels, or of general hunger for land; as, in short, a pointless obstacle to agricultural progress on a par with sacred cows and excessive numbers of feast days, to be cleared away, if necessary by force, as soon as possible. Even so sympathetic and thorough a study as Kenneth Thompson's *Farm Fragmentation in Greece: The Problem and Its Setting* (1963) slips into this view.[1] He concedes that scattering reduces risk, but applies the argument only to fruit and vegetable crops, which are especially vulnerable to localized frosts and hailstorms. He treats the reason given by the inhabitants of one of his sample villages for their opposition to consolidation of plots—"Why should the plots be all together? We are more secure this way: fire, bad weather, etc."—as the prejudice of a benighted peasantry.[2]

In the Greek case and in other cases of scattered holdings past and present it has never been explained why peasants are so often opposed to consolidation if, as is commonly supposed, output was markedly higher when plots were consolidated. Since the English, French and Swedish examples of the eighteenth century, one government after another has passed laws designed to eliminate scattering by persuasion, subsidy, or compulsion, and it would be difficult to explain their painfully slow achievement of success if scattering had no advantage. The Dutch reallotment act of 1924, amended in 1938 and later, for example, made consolidation compulsory if a majority of either the landowners or the land voted by its

owners favored it, and provided generous subsidies (all the costs incurred if the attempt to reallot the holdings failed). Nonetheless, in the early 1950's consolidation of plots in the Netherlands was far from complete (Vanderpol. In Parsons, *et al.*, pp. 548–54). The first of many consolidation acts in Germany was Hannover's in 1848, yet to this day farms in parts of Germany, especially the southwest, are scattered (Mayhew, 1973, pp. 178–99). Official concern with scattering, embodied at the state level in a series of consolidation acts, is half a century old in India, yet the problem (for so it is viewed) remains (Agarwal, 1971).

When they have looked beyond mere peasant conservatism or peasant jealousy for explanations of the opposition to consolidation a few historians and economists have come to emphasize risk aversion. Among the reasons Hungarian peasants rejected consolidation in the 1850's was their fear that natural disasters would destroy a family's whole crop (Molnar, 1971, II, p. 37). A century later, in a wholly different environment, as John W. Thomas, an economist with the Development Advisory Service, discovered, the logic was the same: in Bangladesh (then East Pakistan) in 1970 peasants "were strongly opposed to consolidation since fragmentation of land holdings was their prospective protection against loss of crops due to natural disasters," especially flooding that would leave high land (a mere six to ten feet above the rest) untouched.[3]

Anthropologists especially have been less liable than most historians and economists to dismiss opposition to consolidation as an irrational attachment to old forms. The Hopi Indians of the American Southwest in the 1930's scattered their plots of maize, the Katcina clan in one village holding six plots scattered over a 6 mile square area. As C. Daryll Forde explained:

> This dispersal is of very great practical importance since it reduces the risk of crop failure; where the crop on one group of fields may wither from drought or be washed away by floods there remains the chance that the others will be spared. In particular, disastrous floods rarely occur in all the flats in the same season. The lands close in to the mesa and those out in the middle are still more definitely reciprocal. In an abnormally wet year, when many of the latter are liable to be destroyed by the high floods, the scarp plots are well watered, while, on the other hand, in dry season when they in their turn are likely to be parched out, enough water is usually brought down by the streams to afford a harvest for the mid-valley fields (Forde, 1934, p. 234).

According to another anthropologist, Alan Hoben, scattering of plots by the Amhara farmer of Ethiopia "is highly desirable . . . for by providing him with fields of different qualities it enables him to diversify his crops and to reduce the risk of total crop failure." Attempts at imposing land reform on the Amhara have resulted in armed rebellion, most recently in 1967–68, when several hundred people were killed. Hoben remarks: "If a program of land reform is to be effective it must be based on a model . . . illuminating the rational process through which

people make decisions about land instead of simply attributing these decisions to the dead hand of tradition." (Hoben, n.d., pp. 2, 11–12, and 34.) In view of such an attitude it is not surprising to find testimony of risk aversion causing scattering in a wide variety of anthropological studies, of Tanzania, for example, or of southwest Switzerland or of Brazil.[4] There is a good deal of testimony, in short, that the elementary wisdom of diversification in a dangerous world has appealed to peasant farmers and graziers as much as to urban ship owners and merchants. "Give a portion to seven, and also to eight," said Jesus, son of Sirach, "for thou knowest not what evil shall be upon the earth."

THE HISTORY OF RISK

Encouraging though it may be, testimony that aversion towards risk explains scattering elsewhere does not prove that it explains scattering in England. What is required is English evidence. English peasants never told why they scattered their holdings, perhaps because they or their rulers, speaking through the spare Latin of court rolls, could not be bothered to recite the obvious. Even if they had told why, of course, their testimony—"We are an egalitarian community of shareholders and wish to equalise class-by-class the quality as well as the quantity of land," or "We, like stockbrokers, wish to hold diversified portfolios"—would not be conclusive, for men are not always reliable reporters of their motives. Proofs of an explanation of scattering, then, must rely on its fit with facts other than direct testimony.

Chief among these facts is consolidation. Scattering was not always or everywhere present in England. By the eighteenth century open fields in their full-blown form were confined chiefly to a great triangle defined by Yorkshire in the north, Wiltshire in the south, and Norfolk in the east; yet open fields had once existed outside the triangle, in Cornwall, for example, or in Durham. And within the triangle some holdings or villages were consolidated before the eighteenth century or, indeed, before the fourteenth. An advantage that the hypothesis of risk aversion has over others is that risk can vary enough to explain these varying degrees of scattering, whereas the alternative hypotheses, of Germanic egalitarianism or communal clearing or joint plowing, are reduced to making arguments for action at a distance. Partible inheritance, the leading contender since Joan Thirsk put the weight of her scholarship behind it, is a case in point (Thirsk, 1964 and 1973). The very place where partible inheritance among peasants survived the longest, the southeast of England, was among the first to consolidate; the very place where primogeniture began earliest, the Midlands, was among the last.

The hypothesis of risk aversion does not depend on action at a distance, for risk and the aversion to it moved during the widespread consolidations of the seventeenth and eighteenth centuries in the right direction at the right time. The riskiness

of yields due to disease and weather, for example, was being reduced by new varieties of corn in English agriculture from an early date. In the early seventeenth century there was developed in the south Midlands red-stalked wheat, more resistant to smut, a fungus which destroyed whole stands (Thirsk, 1967, p. 168). Early-ripening barley was another among many innovations of the seventeenth century that reduced risk, the risk in this case of wet, cold springs: barley could be sown in May rather than in March, yet still yield a crop (Thirsk, 1967, p. 170). The advances in the control of the water reaching the crop, that began with floating meadows in the seventeenth century and ended with the widespread use of underdrainage in the nineteenth, amounted to a reduction of the risk of unseasonable rain. Drainage is particularly difficult in regions with clay rather than sand or chalk soils, and it therefore comes as no surprise to find that clay characterized much of the soil of the Midlands, late enclosed. Clay is impermeable and holds a flood. Furthermore, it is dangerous to stir clay soils while they are still wet, because the soil acts then like clay in the hands of a potter, sticking to the plow and hardening on the ground into an unbreakable crust. About 1420 the anonymous English translator of a textbook on agriculture put the matter so: "The fenny feeld is not forto plowe./Lest all the yere it after be to tough/To plowe, eke, as men saith, noo thing wol growe/Thre yere on landes drier than ynough/And rain betwet," that is, nothing will grow for three years on [clay] lands that have become dry, then rained on, then plowed before becoming dry again (Lodge, 1873, p. 45).[5] A wet spring could make it impossible to prepare the land for barley, however rich the crop might be if the land could be plowed. It is significant, therefore, that in the two centuries from the middle of the seventeenth to the middle of the nineteenth, bracketing the most intense period of consolidation, corn production moved out of the wet clay valleys and onto the sands, chalks and high ground (Jones, 1964, pp. 110–28). This shift, in turn, was made possible by new and more reliable animal fodder (the turnip and, by the time of the Napoleonic Wars, the swedish turnip, which was drier and less subject to the risk of rot) and by improved transportation which brought bread to the specialized grazier and dairyman cheaply. And improved transportation itself reduced risk, by increasing the varieties of weather and soil represented in a single market area and therefore decreasing the variability of prices for the market as a whole.

There is some reason to believe that these events and others increased the uniformity of yields within a village, reducing the advantage of a diverse holding: controlling the flow of water in a field, eliminating partial theft and trampling of crops, and reducing the scattered attacks of mold and the like would make various parts of a scattered holding vary in yield more uniformly in the seventeenth century and after than they had before. There is some reason to believe, too, that agricultural innovations in the seventeenth century increased the cost of the insurance achieved by scattering. Flooding and draining a holding three or four times a year to yield a series of rich crops of hay is more difficult, though not impossible, if the

holding is in scraps in the midst of other men's scraps than if the scraps are thrown together. Further, as an enthusiast for enclosure put it in 1769, "Land, which requires to be kept in Tillage, is less incommoded by the Open Field State, than that which is fit for Pasture or Dairy" (Homer, 1769, p. 8). The shift in many open-field regions from specializing in raising grain to specializing in raising livestock—and the greater importance of livestock in the life of mixed farms after the development of cheap winter fodder—would on this account be a reason for consolidation.

The central point, however, is that in the seventeenth and eighteenth centuries the new affluence of farmers and the new opportunities for employment outside of farming altogether reduced the value of insurance achieved by scattering. Gregory King believed that the family income of farmers and lesser freeholders was about £50 a year in 1688 (Thirsk and Cooper, [eds.], 1972, p. 780). Yet, to give an example from one locale which could be duplicated elsewhere, a thirty-acre farmer in mid-Essex by around 1700 held equipment, stock, furniture, jewelry, notes and cash at his death worth twice this figure.[6] Improvements in agricultural practice (among them, indeed, consolidation) made such accumulation of reserves against disaster possible. In Britain and the Low Countries, B. H. Slicher van Bath puts the resulting increase in yields of grain per bushel of seed from the sixteenth and seventeenth centuries to the turn of the nineteenth century at 50 percent, and Eric Kerridge puts it at a larger figure in England, concentrated before 1650 (Slicher van Bath, 1963, p. 16; Kerridge, 1968, pp. 330–331). The higher yields, moreover, reduced the probability of crop failures and reduced still further the probability of successive years of dearth, distressingly common when yield/seed ratios were low and the seed eaten in a hungry year. Little wonder, then, that the periodic crises of subsistence that have fascinated students of the *ancien régime* in France were by the seventeenth century unknown in England (Lastlett, 1965, pp. 113–114). And even when a man's harvest did fail, his income from the expanding industries of the countryside did not; at the end of the seventeenth century only 40 percent of the income of England and Wales was earned in agriculture (Deane and Cole, 1964, p. 156)[7]. By the standards of earlier times, then, English agriculture on the eve of massive enclosure was rich and diverse, and a device for reducing the risk of starvation might be expected to lose some of its charm.

THE LOGIC OF SAFETY FIRST

The question remains whether before enclosure the device worked. The proposition that in some degree scattering served to reduce risk is plausible on its face, as is, say, the proposition that scattering served to equalize the inheritances of siblings in some degree. The nub of the issue is, in what degree? The hypothesis of risk aversion must pass the test of quantitative bite.

The simplest way of showing that it does is to compare the total gains and losses

of adopting scattered rather than consolidated holdings. And the simplest way in turn of bringing the gain in lower variability of income and the loss in lower average income into the same unit of account is to measure their contributions to avoiding disaster. On this view the peasant's purpose was to reduce the probability of his income falling below the level that exposed him to debt, hunger, disease or, in the limit, death by starvation. He sought, in short, safety first.

Figure 1. Reducing the Probability of Disaster by Reducing Variability at the Cost of a Reduced Average.
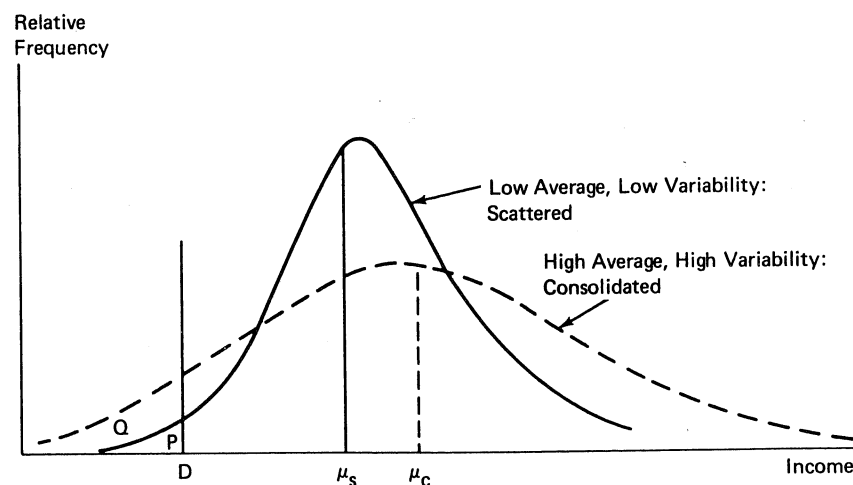

Figure 1 illustrates the choice between an income before scattering that is high on average but highly variable as well (the dotted curve), and an income, after scattering, that is lower on average but less variable (the solid curve). The level of disaster is D, and a peasant who chooses to scatter his plots, accepting the lower average income (μ_s) in exchange for the lower variability, faces a probability of disaster represented by the area under the solid curve to the left of D, area P. The peasant who chooses to consolidate his plots faces the larger probability, Q + P. In this case, then, scattering is desirable: so much lower is the variability of income that disaster is less frequent.

It need not always be so. If the loss in average income is large, or the reduction in variability small, or the level of disaster high, scattered holdings may be more rather than less dangerous than consolidated holdings. The balance of advantage for normal distributions of yields depends on whether or not scattering raises the

distance of disaster from the average, measuring the distance in units of standard deviation. In other words, speaking of D as the disastrous income, of μ as the average income, and of σ as the standard deviation of income, scattering reduces the probability of disaster if it causes $(\mu - D)/\sigma$ to rise.

This measure in English open fields, detailed in a moment, is given in Table 1.

Table 1. The Average and Standard Deviation of Income for Consolidated and Scattered Holdings.

When Disaster = 50

	Average Income	Coefficient of Variation	Standard Deviation	Distance from D	Probability of Disaster	Frequency of Disaster
Consolidated	110	.440	48.4	1.24	.108	every 9.30 years
Scattered	100	.347	34.7	1.44	.075	every 13.4 years

The results are strong. With scattered holdings peasants faced disaster—disaster not meaning, of course, starvation for everyone in the community, but misery for most that was worthy of memory, prayer and fear—about one year in thirteen. With consolidated holdings, forsaking the advantages of diversification, they would have faced it about one year in nine. To put the case another way, scattering doubled the probability of surviving twenty years and tripled the probability of surviving thirty years without disaster.

THE RISKS OF MEDIEVAL AGRICULTURE

The task now is to show that the entries in the table are correct. To begin with the entry for which the evidence is most rich, the standard deviation of income from year to year in English open fields was indeed high, certainly as high relative to an average income of 100 as 35. In plain terms, the figure asserts that in one year out of three incomes would be above 135 or below 65. The records of medieval yields on which the assertion is based, sad to say, are not ideal, for they are records from the large demesne farms worked directly by the lord's servants rather than from the small rented farms worked by the peasants. It was peasants, not lords, who were achieving insurance by scattering their plots, but the records relate to lords, and to the record-keepers among these, chiefly ecclesiastical, who would often be exceptional in other ways as well. The direction of the bias, however, is plain. The variability of yields on peasant holdings, poor land worked with poor methods, is likely to have been if anything larger than it was on the demesnes, in which case the calculated variability is a lower bound on the truth.

This lower bound, then, was high, not only because medieval farming, even of a lordly sort, was so much more vulnerable to weather and other hazards than is modern farming—protected by fertilizers, drainage pipes, rapid harvesters, and pesticides—but also because so large a share of the miserable yield had to be put back into the ground as seed. On the 102-acre demesne farm of Bladon, now near Blenheim Palace in Oxfordshire, one of a group of manors granted in 1704 to the first Duke of Marlborough by a grateful queen and country, the standard deviation relative to the gross average (that is, the coefficient of variation) of wheat produced in 1243–49 was .20.[8] In view of the uncertainties surrounding the definition of the customary "acre," yields must be expressed as yields per unit of seed, both terms of which are known from the "issue of the grange" for the year of harvest and the year of planting. The net yield of seed for next year, then, can be approximated by the gross yield per bushel of seed minus one, it being this net yield alone that is available to be eaten if one is to eat next year as well.[9] On the demesne of Bladon the gross yield of wheat was only 2.6 bushels of output per bushel of seed, on the average, implying a coefficient of variation calculated from the net yield more than half again as large as that calculated from the gross yield, namely .33 rather than .20.[10] More dramatic cases of the magnifying effect of low yields on variability are not difficult to find. On another manor of the Woodstock group, Combe, the coefficient of variation of oats produced was .32. But so low was the yield (1.69 bushels per bushel of seed) that the coefficient of variation of oats consumed was .78. For the four demesnes in the group the results are as follows:

Table 2. The Coefficient of Variation of Yields Net of Seed, Woodstock Manors 1243–49.

| | | Demesne of: | | | |
	Bladon	Combe	Handborough	Wooton	*Average*
Crop:					
Wheat	.33	.41	.35	.82	.48
Barley	.16	.76	.46	.39	.44
Oats	.80	.78	.43	.53	.64
Average	.43	.65	.41	.58	.52

Source: Ballard, 1908, as compiled in Slicher van Bath, 1963.

Such figures can be supplemented elsewhere, and vary a good deal. At Oakington in Cambridgeshire, for example, the coefficient of variation in the net yield of wheat from 1362 to 1409 was .32.[11] At Hurdwick in Devon the coefficient of variation in the net yield of large oats over 13 years scattered from 1412 to 1537 was .47 (Finberg, 1951, p. 112). By far the most complete medieval English yields, however, are those of the forty or fifty demesnes of the Bishop of Winchester in the thirteenth and fourteenth centuries, compiled recently into what

must be considered their definitive form by J. Z. Titow in his *Winchester Yields: A Study in Medieval Agricultural Productivity* (1972). The Bishop's estates were largely in Hampshire and neighboring counties in the south of England, a drawback when using them to infer the conditions of agriculture in the heartland of the open field further north (although the south too was in open fields), especially considering that nearly all the estates were in what Eric Kerridge describes as the Chalk Country, in which the "warm and dry" soils drained much better than did usually the "heavy, cold, wet soils on impervious and retentive bases" of the Midland Plain (Kerridge, 1973, pp. 77, 84; Kerridge, 1968, pp. 29, 42, 91). The contrast in soils, though, is likely if anything to bias the results towards a too low rather than a too high estimate of the hazards of farming.

It is tempting to calculate coefficients of variation over the entire century and a half of this magnificent collection of yields, but the temptation must be resisted. What is relevant for the behavior of peasants is the variability of income around the average income they had come to expect. Whatever the expected average may have been, it was certainly not the average calculated from 1211 to 1349, except perhaps for a 150-year old peasant with a retentive memory and little appreciation of trends in yields. What a peasant in, say, 1340 had come to expect for the yield of 1341 could be estimated as a moving average or as some more sophisticated average of past yields, but it suffices here to limit the calculations to short periods, perhaps 15 years, over which useful memory extended. In the 15 years from 1335 to 1349, for example, on demesnes that had information for all years, the results for the three major crops are:

Table 3. Average Coefficient of Variation for Three Crops on the Winchester Demesnes, 1335–49.

	Wheat	*Barley*	*Oats*
Number of demesnes	35	28	20
Average coefficient of variation (net of seed)	.42	.35	.55
Standard deviation of the average	.09	.12	.15
Standard error of the average	.02	.02	.03

Although the variability is less in these manors in the Chalk Country, the pattern among crops is the same as it is in the Woodstock manors on the edge of the Midland Plain: barley is the least variable, oats the most; a reasonable average of all three crops for England as a whole being .46 or so.

The yields of the three, however, were not perfectly correlated from year to year, making the variability of the income from a bundle of the crops less than the variability of each. The question is, how much less? It is convenient in answering the question to develop a formula used intensively in the sequel that relates the

coefficient of variation in yield of a bundle of crops (or of pieces of land) to the average coefficient of variation of the individual crops.[12] Call the variance of the entire bundle of N crops σ^2, the variance of the ith crop s^2_i, and the covariance between the ith and j^{th} crops s_{ij}. If the average output of each crop is defined to be 1.0, then s_i will be the coefficient of variation of the ith crop and σ the coefficient of variation of income. If the crops make equal contributions to income, the weight of each in the total will be 1/N. Since the definition of the correlation coefficient, R_{ij}, between the ith and j^{th} crop is s_{ij}/s_is_j, one can make the substitution $s_{ij} = s_is_jR_{ij}$. With these preparations it follows from the algebra of variances that:

$$\sigma^2 = (\tfrac{1}{N})^2[\sum_{i=1}^{N} s_i^2 + \sum_{\substack{i=1}}^{N}\sum_{\substack{j=1\\i \neq j}}^{N} s_is_jR_{ij}] \tag{1}$$

This equation is not as unenlightening as it looks at first. The typical term of the first sum in the brackets will be s^2, the average variance. There are N of these in the sum, suggesting that one replace the first sum by Ns^2. The typical term of the second, double sum will be s^2R, the average variance multiplied by the average correlation coefficient, because s_is_j will typically be close to s^2_i or s^2_j. There are N (N-1) of these in the double sum (not N^2, for terms like $S^2_3R_{33}$ are excluded by the condition that i not equal j in the sum), suggesting that one replace the double sum by $N(N-1)s^2R$. The result is:

$$\sigma^2 \cong (\tfrac{1}{N})^2[Ns^2 + N(N-1)s^2R] = s^2(\frac{1 + (N-1)R}{N})$$

Taking square roots:

$$\sigma = s[\frac{1 + (N-1)R}{N}]^{1/2} \tag{2}$$

This relation between the coefficient of variation of single crops and a bundle of crops is an approximation, but its simplicity is well worth its trivial inaccuracy.[13] Observe that if R = 1 or N = 1, then σ = s; the coefficient of variation is not reduced if the yields of the various types move in lockstep or if, equivalently, only one type is held. When R = 0 the equation is simply $\sigma = s/\sqrt{N}$, the coefficient of variation falling off continuously (if at lower and lower rates) as the number of types increase. As N gets large, σ approaches $sR^{1/2}$, this being, therefore, the

maximum effect of diversification in lowering the variability of income. When two types (N = 2) move exactly inversely (R = -1), then σ = 0; by holding two such types all variability of income is eliminated.[14]

All that is now required to arrive at an estimate of the variability of income is evidence on R, the average correlation among the yields of the major crops. The Winchester yields make possible the calculation of this correlation crop-by-crop, not only within a village but also—the more relevant calculation for a peasant holding plots widely scattered over the face of a large village—between two neighboring villages. For the ten villages that can be paired as neighbors, less than three miles or so from each other, the results are:

Table 4. Correlations of Crops Within and
Between Neighboring Winchester Villages, 1335–49.

	Wheat-Barley	Wheat-Oats	Barley-Oats	*Average*
Average R within the 10 villages	.38	.27	.42	.36
Average R between the 7 close pairs	.35	.21	.32	.29

Notes: The pairs are Cheriton-Beauworth, Cheriton-Sutton, Sutton-Alresford, High Clere-Woodhay, High Clere-Burghclere, Burghclere-Ecchinswell, Twyford-Stoke.

It is no surprise that the between-village correlations are less than the within-village correlations (albeit slightly so for the correlation of wheat and barley); the correlation falls with distance, a fact to be extended and applied soon. What is relevant here is that the average correlation, however it is measured, is low, with the result that the coefficient of variation of income was a good deal lower than the average coefficient of variation of individual crops (.46), in this case by the factor $\left[\frac{1+2(.29)}{3}\right]^{1/2}$ = .73. The coefficient of variation of total income on a scattered holding, then, was (.46) (.73) = .34. Allowing for a minor adjustment to be made later, the calculation confirms that the coefficient of variation of income was indeed .347, or near enough.

PRICES, RENTS, AND RISKS

There remain two amendments to the estimate, either of which, if potent, could make it as it stands radically misleading: first, that the risks of agriculture were price as well as yield risks; secondly, that the peasant's income was not the whole of the crop, but the residual after payment of heavy tithes and rents. As it happens, neither is potent.

Consider the risks of fluctuations in prices. If prices matter at all, it is relative not absolute prices that matter, for a doubling of all prices (general inflation) does not

affect real income. In other words, the additional uncertainty of real income arising from the opportunity to exchange barley, say, for wheat depends on fluctuations in the price of barley relative to the price of wheat. The real income from barley is $(P_B/P_W)Q_B$, and the question is whether the variability of this is the same as the variability of the physical yield of barley alone, Q_B. Whether it is or not depends, clearly, on how the yield of barley is related to its price relative to wheat. On the one hand, in an isolated village trading in its own narrow market, a failure of the barley crop would drive up the relative price of barley, offsetting to some degree the drop in income (expressed in wheat) and lowering the variability of income. On the other hand, in a village trading in a wide market, a failure of its own crop would produce little offsetting. Crops elsewhere, poorly correlated with the crop in the afflicted village, could cause the price to fluctuate perversely, increasing the variability of income. To be specific, if the output of barley and its relative price are normally distributed, have a correlation coefficient, r, and have each a coefficient of variation s and c, then the coefficient of variation of their product is:[15]

$$[s^2 + 2rsc + c^2 + (1+r^2)(s^2c^2)]^{\frac{1}{2}} \div (1+rsc)$$

The value of s is, as was shown earlier, .46; it is the average coefficient of variation of wheat, barley and oats—"barley" standing in this discussion for any one of the crops. The value of c, the coefficient of variation of the relative price of a crop, requires prices for two crops for the same set of years. From the fragmentary evidence available for medieval England it appears to be about .25. In Oakington, Cambridgeshire for the thirteen years from 1282 to 1314 in which prices of both barley and wheat were reported, the value was .24, and for the fourteen years from 1319 to 1409 in which prices of both black peas and wheat were reported, it was .29 (Page, 1934, pp. 318–28). A longer series is available for large oats and wheat at Hurdwick, Devonshire; and for twenty-eight pairs of prices from 1398 to 1524 the coefficient of variation of the relative price of oats is .25 (Finberg, 1951, pp. 116–119). The correlation between a crop's yield and its relative price, r, requires both the prices and the yield for the same set of years, and is therefore more difficult to measure. For the seven years out of the twenty-eight at Hurdwick in which all these are available, r is −.38. The negative correlation is no surprise in view of late medieval, still less early medieval, costs of transportation. After a bad hay crop on his Sussex farm in 1777, William Marshall reflected, no doubt gratefully, that "The price of *corn* is regulated by the *crops of Europe*; but the price of *hay* is settled by those which happen within the *circuit of a few miles*" (1777, his italics). What was true of hay in the eighteenth century was true of most crops in the fourteenth century. In any event, the exact value of r, so long as it is

negative, is not important. For s = .46 and for various values of c and r, the value of the expression is:

Table 5. The Coefficient of Variation of the Real Value of a Crop for Various Choices of *r* and *c*.

		Correlation between Yield and Relative Price			
		0	−.20	−.40	−.60
Coefficient of	.20	.51	.48	.45	.41
Variation of	.25	.54	.50	.47	.42
the Relative					
Price	.30	.57	.53	.49	.44

The most extreme values consistent with what is known about medieval agriculture produce a coefficient of variation including fluctuating prices (.57 to .41) near to the coefficient of variation excluding them (.46). Fluctuating prices did not greatly add to, or subtract from risk.

The other amendment to the simple measure of risk looks at first more potent. Peasants did not earn the gross output of their land, for in the opinion of the king, the church, and above all the lord of the manor, it was not their's to earn. The church's tithes were taken in the field, and are therefore already removed from the yields. But the lord's rents of all sorts, amounting to half of the gross yield (Postan. In Postan, [ed], 1966, p. 603) and to still more of the yield net of seed, are not. Were the rents immutable and collected in kind, their effect on the variability of peasant incomes would be similar to the effect of the fixed outlay for seed, and much stronger. The average gross yield of grains on the Bishop of Winchester's demesnes in the first half of the fourteenth century was about 3.2 per bushel of seed.[16] A coefficient of variation of income (after subtracting seed alone) of .35 or so implies a standard deviation of .78 per bushel of seed. Consequently, if the lord took in rent each year half the average gross yield (namely, (.5)(3.2) = 1.6), the coefficient of variation of the income remaining would have been (.78) ÷ (3.2−1.0−1.6) = 1.30! Were starvation half the average residual income [(.5)(.60) = .30] peasants would have starved in four years out of every ten. That they did not suggests that the reasoning is faulty.

The fault lies not in the statistics of yields or average rents, which are reasonably well founded, but in the assumption that the lord took his rents in kind. By 1300, rents all over Europe, and in particular in England, were expressed largely in money (Postan. In Postan, [ed.], 1966, p. 603; Duby, 1968, p. 238). Since the price of grain varied inversely with the size of the crop, the real, as distinct from the money burden of rents, would decline in years of crop failure. Algebraically

speaking, the peasant's net income in money was $PI = PQ - M$, that is, the value of his net income (PI) was the value of his output (PQ) minus his money rents (M); his real net income, then, was $I = (PQ - M)/P = Q - (M/P)$. The output of a peasant having diverse plots in a village—note this qualification, for it will be significant when thinking of a peasant without diverse plots—would have moved up and down with the output of the village as a whole, and therefore up and down, though imperfectly correlated, with the output in the local market. The peasant's output, therefore, would have moved inversely with the price, as, say, $P = aQ^{-b}$. Consequently, the peasant's real income would have been $I = Q - (\frac{M}{a})Q^b$. The question is, will the coefficient of variation of real income (I) be greater than, equal to, or less than the coefficient of variation of gross output (Q)? The answer depends on b, the slope of the inverse relation between price and quantity. When its absolute value is 1.0 the peasant's real income is $I = Q - (\frac{M}{a})Q^{1.0} = Q(1 - \frac{M}{a})$, that is, real income is simply proportional to gross output and the coefficients of variation of output and of income are the same.

The absolute value of the coefficient b, in fact, appears to be near or a little below 1.0 implying that fixed money rents were equivalent to a fixed share of the crop. The most relevant evidence is for wheat, the cash crop of the peasant. Taking logarithms of both sides of the supposed relationship between price and quantity gives the equation to be fitted to the evidence, namely, $\log P = \log a + b \log Q$. The wheat output net of seed (which is what reaches the market and affects price) is, like the price, undoubtedly measured imperfectly: seed requirements changed from year to year, the output of the demesne does not reflect perfectly the output of the peasantry's land, and so forth. It is well known that errors in the independent variable in a simple regression of the sort proposed will bias the estimate of the slope, b, towards zero. The simplest solution to the problem is to regress both P on Q and Q on P, and be content with an upper and lower bound on b, thus:

Table 6. Regressions of P and Q for Wheat
at Mardon and Ecchinswell, 1297–1349.

Period	$\log P =$ $\log a + b \log Q$ $b =$	$\log Q =$ $\log a + b \log P$ $1/b =$	Average	R^2	Number of Years
1297–1318	−.61	−1.19	−.90	.51	20
(1313–1318)	−.79	− .85	−.82	.92	6
1325–1332	−.46	−4.37	−2.4	.10	3
1335–1349	−.38	−1.15	−.77	.33	15
(1337–1341)	−.28	− .53	−.40	.53	5

Source: Prices of wheat from Titow, (1969), pp. 98–99, yields net of seed the average of the two places, from Titow, (1972). The yield (calculated at the end of September in the harvest year) is matched with the price of the following year.

The lower bound is the first column, the upper bound the second, and their average (which would be the best estimate were the errors in P and Q similar in magnitude) the third. The regression is calculated for three periods instead of the entire period in order to allow, in a rough way, for trends, which would obscure the short-term relation between P and Q. The years in parentheses are sub-periods around two especially bad episodes, 1315–16 and 1339. In the regression with the best fit (1297–1318), the average of the coefficient b estimated in both ways is −.90.

The evidence for other crops, times and place is not ample because the calculation requires a set of years close enough to each other to fit the horizon of a peasant and to escape trends of inflation and deflation, both yields and prices. Oakington, Cambridgeshire meets the conditions for two crops, wheat and black peas, in the late fourteenth century.

Table 7. Regression of P and Q for
Wheat and Black Peas at Oakington.

	$\log P =$ $\log a + b \log Q$ $b =$	$\log Q =$ $\log a + b \log P$ $1/b=$	Average	R^2	Number of Cases
Wheat, 1390–1408	−.28	−4.35	−2.32	.06	9
Black Peas, 1362–1375	−.23	−1.17	− .85	.27	10

Source: Page, (1934), pp. 319, 328–30.

The fits, again, are poor, but the values of b are consistent with the previous table. With results such as these it would not be impossible, of course, for the absolute value of b to be as small as, say, .50; in which case the presence of rents taking half of average output would raise the coefficient of variation from .35 to .50[17]—not the dramatic rise implied by rents fixed in real terms, but notable. The best estimate, though, is that the absolute value of b was 1.0 or a little less, perhaps .9 (which would raise the coefficient of variation from .35 to .38) or .8 (which would raise it to .41). The lord might ignore the pleas to reduce rents in a bad year, yet the rise in price would accomplish nearly the same thing. By fixing rents in money he shared with his tenants in the risks of the harvest, much as lord and tenant did in explicit agreements to sharecrop, rare though such agreements were in England. The insurance achieved by scattering was additional to the greater insurance— relative to the alternative of fixed real rents—of fixed money rents. In short, the coefficient of variation of physical output (near .35) can stand for the coefficient of variation of servile incomes.

DISASTER

Having established that the entry for the coefficient of variation of income in Table 1 of a while back is correct, the next step is to establish that the entry for the level of disaster of 50 (relative to an average income of 100) is correct. There are several ways of doing this. The first and least conclusive way is to measure yields in disastrous years. A yield in famine of one-third to two-thirds of the average is a traditional estimate, making one-half plausible.[18] The evidence for medieval England, in particular for the great famine of 1315-17, supports this judgement. One cannot merely calculate for each Winchester demesne the deficiency of the crop in a bad year, say 1316, relative to the typical yield, and then average the result over all the demesnes, because even in generally disastrous years, such as 1316, some villages were not struck by disaster. What is relevant is disaster in a village relative to normal yields when it strikes, not an average over lucky and unlucky villages. Set off from the others, midway between Portsmouth and Southampton, Fareham, for example, was lucky: while most of the villages suffered a large drop in the yield of wheat from 1314 to 1315, and many a further drop in 1316, Fareham's fell slightly in 1315 and rose sharply in 1316; its barley yield rose in both years; and only its oat yield fell, although remaining above the average of earlier years. To include Fareham or villages like it would distort the calculation. How to exclude villages, however, is uncertain. If one selects those villages in which the years 1315 and 1316 were in fact the exceptionally bad years described by contemporaries (Lucas, 1930), that is, in which the yield of at least two of the major grains was at its lowest or its next to lowest in one of these two years relative to the four years before 1315 or after 1316, there is some assurance, arbitrary though it may be, that one is looking at villages actually experiencing disaster in 1315 or 1316. Many villages did not have complete information. Since the years 1319 and 1321-23 are unavailable for any of the villages, 1320 and 1324 were taken to fill out the test of four years before and after the bad years. For the 12 villages with complete data Table 8 exhibits the ratios of incomes in 1315 and 1316 to the average incomes in the villages 1300-1324 (both terms in the ratio being simple averages of the net yields of wheat, barley and oats).

The observations with asterisks pass the test of unusual lowness of yield for that year, six passing it in each year: six out of every twelve villages does not seem unreasonable as the proportion experiencing disaster in one of the most severe famines in European history. Still, as promised, the test is inconclusive. The range in the ratio of famine income to average income in the villages that pass it is − .02 to .74, with an average of .42. The difficulty is that even if the test correctly selects only villages experiencing disaster, any average of their experiences will understate the level of disaster, some villages (in this case, patently, Ashmansworth and Ecchinswell in 1316) reaching down far below it. Were it not obvious that the level of disaster relative to the average varies from village to village the solution would

Table 8. Ratio of 1315 and 1316 Yields to Average Yields 1300–1324.

	1315 Income Relative to 1300–24	1316 Income Relative to 1300–24
Ashmansworth	.41	−.02**
Ecchinswell	.47	−.02**
West Wycombe	.37*	.32*
East Meon	.63*	.35**
Beauworth	.75	.37
Crowley	.81	.63**
Bentley	.37*	.43*
Fonthill	.64*	.81
Alresford	.74**	.84
Bitterne	.63*	1.16
Downton	.93	1.06
Fareham	1.18	1.41

Source: Titow, 1972.

* This year is worst or next worst of 1311–1324 (except other of 1315–16 pair) for at least two crops.

** This year is worst of 1311–1324 (except other of 1315–16 pair) for at least two crops.

be simple enough, namely, to select the highest level for villages certified on some other grounds as experiencing disaster (the ideal would be local testimony), in this case .74 (Alresford in 1315). As it is, one knows only that .74 is too high and .42 too low, which is a range around .50, although not a small one.

Another way to show that .50 is a reasonable estimate of disaster relative to average income is to examine disastrous consumption relative to the average. Without entering too deeply the scholarly battlefield over which partisans of one or another view of the standard of living in medieval England fight—a place of hazard for medievalists and of sure death (indeed, disaster) for non-medievalists—some rough estimates may be ventured. M. M. Postan and J. Z. Titow (partisans, admittedly, of a pessimistic view) argue that a peasant family in the thirteenth and fourteenth century, on the premise that land was its only source of income, required, to stay alive, about ten acres.[19] The average acreage with which ten acres is to be compared must be the average for peasants occupied full-time on their land and living above subsistence, because these peasants held most of the tenant land in the village and therefore determined, with the lord, the usual geography of tenant holdings. On 104 thirteenth century manors, Postan found that full virgaters holding 24 to 30 acres (27 acres, say, on average) constituted 22 percent of the tenants, half virgaters holding 12 to 15 acres (13.5 acres on average) 33 percent, and smallholders of less than 10 acres (3 acres on average) 45 percent. Numerous though the smallholders supplementing their income from land by laboring were, they held only (3) (45) ÷ [(3) (45) +

(13.5) (33) + (27) (22)] = 11 percent of the tenant land.[20] On this basis the average acreage of a tenancy above subsistence was [(13.5) (33) + (27) (22)] ÷ 55 = 18.9 acres. Since a bare subsistence yield on 18.9 acres is equivalent to the yield on a holding capable of yielding bare subsistence without outside employment—*viz*, 10 acres—subsistence was 10/18.9 = 53 percent of the relevant average.

A final way to show that disaster was 50 relative to an average income of 100 is to use the observed frequency of disaster. If the standard deviation of income is about 35 relative to 100, as has been shown, then the frequency of disaster, when disaster is 50, is about once every 13 years, and this is roughly the frequency of disaster observed before the agricultural revolution. The normality of the distribution, which is important at other stages of the argument as well, is easy to accept; indeed, what is difficult is to frame tests that have a sporting chance of rejecting it. Evidence from a demesne of 200 acres is inappropriate because, by the central limit theorem, its output may well fit a normal distribution even though 20 acre pieces from the demesne, each of which might make up a peasant's farm, fit a quite different distribution. Evidence from a long period is inappropriate as well, because it is normality over a peasant's life, not over a century, that is relevant to his decisions to insure. Yet if the period is too short there will not be enough observations to put the hypothesis of normality in jeopardy. Technically speaking, the expected frequencies in a chi-square test of goodness of fit must be at least 5 (some statisticians would say 10); the minimum number of classes that leave any degree of freedom for a test of normality when the mean and standard deviation are estimated from the data is 4; therefore the minimum number of years in a test is 20. Three cases of unusually small demesnes among the Bishop of Winchester's that have the requisite data are Bitterne in 1325–49, and Farnham in 1297–1324 and in 1335–49. Income can be calculated on these by averaging the net yields of seed of wheat, barley and oats. Peasants certainly did not grow these crops in exactly the proportions implied by a simple average, but alternative proportions give similar results. It is in any case difficult to find evidence for any assertion about what they did grow other than the useless one that they probably grew all three, wheat to sell for the rent money and the others to eat or to feed to their animals. The results (which embody the Yates correction for continuity) are contained in Table 9.

Notice that the coefficients of variation bracket the earlier figure, .35. And notice too that the larger the acreage the lower is the chi-square, confirming the remark about the central limit theorem coming into play for large acreages. It is in any case difficult on this showing to reject normality. In the peculiar manner of speaking usual when testing hypotheses statistically, were one to reject the hypothesis of normality when chi-square was greater than 1.67 or 1.48 or 1.10, one would expose oneself to a .20 or .22 or .29 probability of rejecting it when it was in fact true, a fairly skeptical position. A plausible alternative distribution—normality of the logarithms of the yield—results in somewhat higher chi-squares (2.16 for

Table 9. Chi-Square Tests for the Normality of Income.

	Number of Years with Data	Size of Demesme (acres)	Average Net Yield/Seed, Three Crops	Standard Deviation	Coefficient of Variation	Chi-Square	Probability of Falsely Rejecting Normality if this was the Critical Level (1 degree of freedom)
Bitterne							
1325–49	22	52	2.13	.608	.29	1.67	.20
Farnham							
1297–1324	21	66	1.68	.597	.36	1.48	.22
Farnham							
1325–49	21	75	2.44	.965	.40	1.10	.29

Bitterne, 3.00 and 1.85 for Farnham) and lower risks of excessive skepticism (.14, .08, and .17) if this distribution is rejected. That the chi-squares are only "somewhat" higher testifies to the difficulty of rejecting any plausible distribution (roughly unimodal) within the constraints of the data. Still, normality is convenient, theoretically unobjectionable, and fits the facts reasonably well.

The evidence for the other half of the present demonstration that disaster was around 50 relative to an average of 100 is evidence on the frequency of disaster. It has its own ambiguities, even aside from the ambiguity in the word "disaster," because the frequency of general disaster in the absence of a perfect correlation between yields in different places would be lower than the relevant frequency, that of local disaster, and it is sometimes unclear whether a frequency is local or general. The Anglo-Saxon Chronicle, for example, speaks of fourteen harvest failures from 975 to 1124, a frequency of about one every eleven years,[21] or one every 12.5 years if failures in two successive years are counted as one, but it is unclear whether this refers to the whole kingdom (in its varying completeness) or to the part of it in which the chroniclers lived. The distinction matters, for it is shown later that the correlation between yields in distant villages within one small part of England was only .40. The effect is apparent in W. G. Hoskin's study of "Harvest Fluctuations and English Economic History, 1480–1619," (1953–54, reprinted in Minchinton, [ed.], 1968, I, pp. 113–115), which uses national average prices of wheat ranged against the literary evidence to identify years of "dearth" (as distinct from bad, deficient, average, good, and abundant harvests). In these 140 years dearth occurred in the country as a whole every 20 years (every 28 years if successive dearths are counted as one); it occurred, however, every 12.7 years (15.6 years) in a limited locale for which a continuous series is available, in Exeter. The local chronicle of Shrewsbury in the second half of the sixteenth century reports a similar interval, of 12.5 years (Hey, 1974, pp. 49–50). One year in thirteen, in short, appears to be a reasonable estimate for a single

locale. Were disaster set at 40 relative to an average of 100 its frequency would be in view of such evidence unreasonably low (every 24 years); and at 60 unreasonably high (every 8 years). Disaster, then, is around 50.

THE EFFICACY OF DIVERSIFICATION

The last piece to be fitted into the evidence for Table 1 is the variability of income on a consolidated, as distinct from a scattered holding. The essential point is that a scattered holding contains many different types of land while a consolidated holding contains but one. Putting all his eggs into one basket, therefore, the coefficient of variation of the income of a peasant working a consolidated holding is higher than that of his more cautious brother working a scattered holding. To speak more quantitatively, recall first that for a single crop the coefficient of variation on medieval demesnes was about .46. Now this was itself the result of a scattered holding: even when demesnes were consolidated (some were not, perhaps the better to insure a bailiff responsible for a fixed annual return to the lord against embarassment) they were large and would contain many types of land, say 15—though it would matter little for the argument if they contained 10 or 20. Suppose that the correlation from year to year in the yields of different types of land was on the average, .60. This is the critical number. According to the formula developed earlier, the coefficient of variation on a holding of 15 types would be related to the coefficient of variation (c) on a holding of 1 type in this way: $.46 = c[[1 + 14(.60)] \div 15]^{\frac{1}{2}} = c(.79)$; from which $c = .58$. For each crop, in other words, a consolidated holding on one type of land has a coefficient of variation of .58. By contrast, a holding scattered over five types (it would make little difference if it was 4 or 6) has a coefficient of variation of $.58[[1 + 4(.60)] \div 5]^{\frac{1}{2}} = .48$. The contrast between .58 and .48 is a measure of the larger part of the insurance from scattering. The smaller part covers familiar ground. As was noted earlier, the three crops peasants grew were poorly correlated in yield. But the crops would be more poorly correlated for a scattered than for a consolidated holding, which fact adds a little to the insurance. If the correlations between pairs of the three crops (distinct from the correlation between places for a single crop, .60) was .36 for a consolidated holding and .29 for a scattered one, then the coefficients of variation of income would be:

Scattered: $.48[[1 + 2(.29)] \div 3]^{\frac{1}{2}} = .48(.73) = .35$

Consolidated: $.58[[1 + 2(.36)] \div 3]^{\frac{1}{2}} = .58(.76) = .44$

These are the figures in Table 1 given earlier. When they are proven, the table is complete.

The question is, was the correlation of yields between plots scattered over a

village two miles or so square about .60? For most city folk, who reckon one bit of dirt or fall of rain much like any other, it is hard to believe such a low figure, although it is not hard for farmers and backyard gardeners. The first class of evidence is botanical and meteorological. "The common Accidents and Diseases befalling Corn in the growth of it, being Meldew, Blasting, Smut," (Enquiries of the Royal Society, 1664, in Lennard, 1932. In Minchinton, [ed.], 1968, p. 165) were fungoid diseases, local in their effects, as might be expected from the random distribution of spores by wind and rain. As Joseph Wilkinson of Yorkshire, responding in 1664 to the Royal Society, wrote: "I have observed in the same field divers parts as were cheryndred [?], some mildewed and blackish, others pure and white, the mildewed a sandy land, the pure a sharp and stony land." (Thirsk and Cooper, [eds.], 1972, p. 152; their remark on "cheryndred.") In similar fashion, birds flock and insects swarm, spotty in their depredations. Hail in England is common in the spring, rare in the ripening season, and "the usual area we should assign to an English hailstorm is a mile or two long and a few hundred yards broad" (Russell, 1893, p. 23). When hail came it could easily damage crops in one part of a village three or four thousand yards broad without damaging those in another part, although it came, on the whole, in the season when it could do the least damage. The last frost in England is frequently spotty in its incidence as well, particularly across slightly different altitudes, and variable in date. Because England's climate is wet, the change in average temperature from season to season is less sharp than it is in continental climates, and a given fall in average temperature (from a cold year or a higher altitude) will therefore produce a more radical shift in the date at which the temperature permits growth (42 degree Farenheit). As a modern student of these matters concludes, "even the several fields of a normal (i.e., non-fruit) farm have each their varying characteristics arising not merely from soil but also from the significant local variations in the incidence of frost" (Manley, 1952, p. 218).

Another, more quantitative class of evidence on the size of R is experimental. The variability of yields over small areas is notorious among agronomists. R. A. Fisher's pioneering work on *The Design of Experiments* was, in large part, devoted to precisely this problem, and one hears echoes of a cautious medieval peasant laying out elongated strips within a furlong block in one part of Fisher's advice for handling it: "each plot must . . . sample fairly the whole area of the block in which it is placed. It is often desirable, therefore . . . to let the plots lie side by side as narrow strips each running the whole length of its block" (Fisher, 1947, p. 65). He remarks, again, that even an area as small as an acre has "considerable greater soil heterogeneity" than a quarter-acre (p. 104). His elaborate techniques for minimizing the uncertainty due to such variation were fully justified by earlier spoiled experiments. In reporting the experiments in rotations on Lansome Field at Woburn beginning in 1881, for example, J.A. Voelcker complained repeatedly that despite an apparent uniformity "the soil of Lansome

Field . . . has been found to be not really uniform enough and the land not level enough to make a really satisfactory experimental field" (Voelcker, 1897, p. 640 and 1884, p. 360). Plots 1 and 4 were quarter-acres a little over 100 yards apart, treated to precisely the same unfertilized rotation. Yet the average yield from the four crops of barley taken from 1885 to 1897 was 13 percent higher on plot 4 than on plot 1; indeed, the yield on plot 4 was higher than on any of the fertilized plots. The correlation of yields on plots 1 and 4 was only .78, despite the care taken to cultivate the plots in the same thorough and expensive way, far beyond the standards of ordinary farming. Even the more successful experiments in the continuous growth of barley in the Stackyard Field at Woburn could produce a correlation of only .84 from 1877 to 1884, between the two unfertilized plots (1 and 7) 100 yards apart (Voelcker, 1897 and 1898, pp. 722, 690–97). The correlation drops sharply for plots treated with different fertilizers but cultivated otherwise in an identical careful fashion. The correlation at Rothamsted between yields of wheat grown continuously without fallow on plot 3 (unfertilized) and plot 2 (fertilized with dung) from 1844 to 1883, for example, was only .55 (Lawes and Gilbert, 1864 and 1884). Plot 2 could stand for the infield and 3 for the outfield in the variety of the open field system common in the Celtic fringe of Britain: the infield, close to the village, received intensive fertilization while the outfield received none.

The experimental evidence, however, has the defects of its virtues. Cultivation was carefully controlled and carefully recorded over a small area, but with the result that the effects of interplot variation, such as local attacks of mold and local peculiarities of drainage were minimized. Because the experimenters were attempting to isolate the effects of particular regimes of fertilization and rotation they spared no pains to eliminate others. In consequence, if the experimental correlations between plots are relevant at all they are relevant only as upper bounds on the correlations to be expected in an agriculture lacking the knowledge or resources to achieve the meticulous standards of the laboratory. The experiments, in short, imply an upper bound on R of .70 or .80.

The best evidence on R is from open field agriculture itself, scarce and ambiguous though the evidence is. Very seldom do the records for a crop of wheat, say, distinguish yields in different parts of a field or village, yet this is what is wanted. Even so methodical a record-keeper as Robert Loder, farming in Harwell, Berkshire in the early seventeenth century, kept records on separate portions of his many different crops only for hay. On three plots of hay not more than a mile or so from each other the mutual correlations 1611 to 1620 were .90, .66, and .37, for an average of .64.[22] A fall in the crop of the Padocke plot in 1612 he interpreted as "the loving and fatherly chastisements of the Lord my God" (p. 36), but the chastisements were not laid on everywhere: the yield of the Town Meade plot increased by over 50 percent in the same year.

In the absence of more evidence of this sort—which in any case could be

expected to exist only in an age of literate and reflective farmers, and which therefore would be to some extent anachronistic when applied to open field farming at its height—one must turn again to the records of demesne farming in the Middle Ages. Many demesnes with records were close to others with records, making it possible to infer from the correlations between villages what the correlation might have been within them. The procedure has difficulties, to be sure. The neighboring demesnes must be quite close, no more than three miles or so apart, to be relevant to the experience of any but a long, thin village. Since few are less than two miles apart (measuring distances from church to church on the modern Ordnance Survey maps) and since, as will be shown in a moment, the correlation falls with distance, the calculated correlations may be too low to represent the correlation facing a peasant in one open field in a village. On the other hand, since the demesne usually took the best land, bottom land in a valley, for example, the correlations may be too high, because the bottom land in one village may be more similar to the bottom land in another than to the land on the village hill. Although Twyford and Stoke are the most distant pair of the Bishop of Winchester's neighboring demesnes examined in detail below (3.3 miles church-to-church) the correlation of their wheat crops is the second highest observed, .84. If these were consolidated demesnes near the center of each village the high correlation would be misleading, for the center of both is on the same bank of the River Itchen with the same (southeasterly) exposure relative to nearby hills.

The evidence, nonetheless, is suggestive. The first insight that can be wrung from it is that the correlation of yield of a crop between two villages, R, does fall as the distance between the two increases. Were this not the case it might be possible to achieve insurance without scattering, for if R were, say, .60 both at a distance of 200 yards and at 2000 yards a peasant could hold a sufficient diversity of land within a small area. One presumes that R would indeed fall with distance, and it is pleasing to have the presumption confirmed for the villages on the Winchester estates, 1335–49. Choosing the dozen less than 3.3 miles apart and setting aside the two pairs, East Meon-East Meon Church and Twyford-Stoke, which fall far off the fitted line for the good reason that they were in different parts of Hampshire from the others, the regression of R for wheat on miles of distance is:

$$R = .95 - .14d \qquad r^2 = .66$$
$$(.09) \quad (.04) \qquad n = 10$$
$$\mathrm{SEE} = .07$$

For each mile of distance of one crop of wheat from another, therefore, the R fell 14 points.[23] It would not, of course, go on falling indefinitely. The correlations in six randomly selected pairs of villages (from 10 to 45 miles apart), compared in Table 10 with the correlations in close villages imply a lower limit on R in Hampshire for the three major crops taken together of about .40:

Table 10. Comparisons of Correlations Between Yields in Close and Far Villages, Winchester Demesnes, 1335–49.

	Wheat	Barley	Oats	Average Equally Weighted
	Distant Villages (n=6)			
Average R	.55	.15	.38	.38
(Standard deviation)	(.18)	(.23)	(.90)	(.09)
	Near Villages (n=9)			
Average R	.68	.57	.66	.64
(Standard deviation)	(.15)	(.15)	(.22)	(.09)
Level of significance of difference	.074	.001	.01	.0001

The last line in the table gives the probability of observing such differences by mere chance if the correlations between pairs of the distant and near villages were in truth the same. That the distant villages have such definitely lower R's is additional testimony to the inverse relationship between R and distance. By this test there is more room for skepticism about the testimony on wheat than on the other crops, although by the regression test less; regressions of R against distance at work poorly for barley and oats, possibly because spring crops depend more than does wheat on variations of soil and the like within distances smaller then the mile or more minimum distance church-to-church in the Winchester estates.

This last possibility finds some confirmation in still another test of the inverse relationship between R and distance, relying on correlations between different crops. If correlations fall with distance one would expect correlations between crops of, say, wheat and barley to be lower between two close villages than within each village. For instance, one would expect the correlation of the wheat crop in Alresford with the barley crop in Sutton (these two crops being about 1.5 miles apart) to be lower than the correlation of the wheat crop in Alresford with the barley crop in Alresford itself (these crops being closer, perhaps—depending on the extent of Alresford—a mile or less apart). The expectation is fulfilled:

Table 11. Correlations Between Crops Within and Between Seven Pairs of Close Villages, Winchester Estates, 1335–49.

	Average Correlations Between:			
	Wheat-Barley	*Wheat-Oats*	*Oats-Barley*	*Average*
Within the Villages	.39	.26	.43	.36
Between the Villages	.35	.21	.32	.29

The figures in the Average column were used earlier to represent the between-crop correlations facing a peasant with a consolidated holding (.36) or a scattered holding (.29). What is relevant here is that the differences between the within-and-between village correlations for Oats-Barley (although not the correlations involving the winter crop, wheat, which display no uniform pattern) fall with greater distance. Regressing the excess of the within-village correlations of oats and barley over the between-village correlation on the church-to-church distance in miles (d) for the seven pairs gives:

$$R_{within} - R_{between} = -.16 + .12d \qquad r^2 = .61$$
$$(.10) \quad (.04) \quad SEE = .07$$

For each mile of distance, in other words, the Oats-Barley correlation falls 12 points further below the same correlation within a village.[24] Notice how similar the coefficient is to the comparable coefficient in the wheat regression given above. The correlations, then, fall with distance.

The other insight that can be wrung from the experience of neighboring demesnes is that the correlation for a single crop over the distances relevant to scattering in open fields is indeed about .60. Since the experimental correlations over small distances are often not much above this level the assertion is not surprising. On the neighboring Winchester estates, to be sure, the average (given in Table 11 above) is a little higher, about .64, implying a still higher figure at lower distances. Yet these demesnes, as was noted earlier, were located on chalk soils, inherently less variable and hazardous in their response to the weather. On the four Woodstock manors at about the same time, located on the edge of the clay soils of the Midland Plain, the average R was well below .60, as Table 12 shows.

Table 12. Correlations Between Yields of Neighboring Demesnes of the Woodstock Manors, 1243–49.

		Combe			*Handborough*			*Wooton*		
		Wheat	Barley	Oats	Wheat	Barley	Oats	Wheat	Barley	Oats
Bladon	Wheat	.12			.39			.80		
	Barley		.60			-.40			.47	
	Oats			-.29			.65			.29
Combe	Wheat				.76			.30		
	Barley					-.51			.17	
	Oats						.046			-.46
Handborough	Wheat							.50		
	Barley								.48	
	Oats									.37

Source: Ballard, 1908, as compiled in Slicher van Bath, 1963.

The average over the three crops for the six pairs (from 1.25 to 3.6 miles apart) ranges from 0 (for Combe-Wooton) to .52 (for Bladon-Wooton), the average over the six pairs for the three crops from .10 (for oats) to .48 (for wheat). The overall average correlation is .24. It is clear that the evidence justifies a choice of R as low as .60.

All the entries in the table describing the choices of a peasant facing disaster have now been confirmed. In particular, a peasant who held a scattered farm faced a standard deviation of income of 35 relative to an average of 100, whereas a peasant who held a consolidated farm faced one of 44.[25] There is, indeed, a reason for believing that the risks of a consolidated holding were even larger. Because of the imperfect correlation between yields in different parts of a village the farmer of a consolidated holding is more lonely in his struggle against hazard than is the farmer of a scattered holding. The income of an open field farmer will fluctuate in much the same way as does the income of his fellows, while an enclosed field farmer goes it alone. One consequence is that it would be difficult for a giver of charity or loans to distinguish avoidable from unavoidable accidents on a consolidated farm. The lord of the manor is more likely to forgive rents in a bad year if all his tenants ask, all with lower crops, than if only a few ask. Another consequence, at a less speculative level, is that the yield of a consolidated holding will be less well correlated with the price of corn, for a holding containing many types of land is more likely to yield well in a year of low prices generally and poorly in a year of high prices than one containing few types of land. As was argued earlier, this offsetting is critical when money rents are a large fraction of gross income. Robert Loder's hay crop in three places can illustrate the point. Table 13 gives the regression coefficients of yield on price and of price on yield for each of the three fields and for the three fields together.

Table 13. Price and Quantity Regressions,
Loder's Hay Crop, 1611-20.

	Lower Bound (b in $P=a\,Q^b$)	Upper Bound (l/b in $Q=aP^b$)	Average	r^2
Town Meade	−.30	−2.56	−1.43	.12
South Marsh	−.49	− .68	− .58	.72
Padocke	−.52	− .66	− .59	.78
Whole Crop	−.67	−1.02	− .84	.68

Source: Fussell, (ed.), 1936, *passim* (e.g., pp. 5–6, 184).

Recall that the closer the coefficient b is to −1 the more completely do variations in price offset the fixity of rents, and the lower is the variability of income. The reliable regressions in the table (South Marsh and the Padocke) give upper bounds on b near the lower bound on b in the regression of the whole crop (the last line).

Had Loder held only one of these fields his income from hay after paying a 50 percent money rent typical of medieval England would have been markedly more variable than it would have been had he held all three.[26] A consolidated holding was a hazardous holding.

THE ROBUSTNESS OF THE RESULT

It is time, at last, to step back from the intricacies of the argument and assess its result. The result is that scattering reduced risk enough to offset its inefficiency: the hypothesis of risk aversion does have quantitative bite. The reader will wonder if the bite comes from some artificially sharpened tooth. Statistically speaking, the result depends on various estimates, any of which may be in error. It is difficult enough in economic history to estimate first moments, as evinced by the long list of controversies that have turned on the value of an average, from the average income of medieval peasants to the average quality of Victorian businessmen; it is still more difficult to estimate second moments, as is evinced by the equally long list of controversies, many of them hopelessly short of a conclusion, that have turned on the value of a variance or a correlation, from the price revolution of the sixteenth century to the standard of living of the early nineteenth. Yet tests of the hypothesis of risk aversion must depend on second moments, for the variability of income lies at its heart.[27] The solution is to find out how the result varies when the estimates vary. Table 14 gives high and low estimates of the variables around the best estimate.

Table 14. Alternative Values of Estimates in a Calculation of Risk.

Variable	Symbol	Low	Best	High
Correlation for one crop	R	.43	.60	.73
Correlation between crops, one village	R_c	.14	.36	.54
Correlation between crops, near pairs of villages	R_s	.07	.29	.48
Coefficient of variation of a typical crop	s	.41	.46	.60
Average income with consolidation, relative to scattered = 100	μ	107	110	113
Level of disaster relative to average income on scattered holding	d	40	50	60

The high and low estimates for R, R_c, R_s and s are meant to represent the averages of the upper and lower halves of their distributions when the best estimate is based on a sample of 15—the number of years used earlier to stand for the extent of the useful memory of peasants.[28] They would be closer to the best estimate if the

procedure were permitted to reflect the larger samples on which the best estimates are in fact based. The high and low estimates of μ and d are merely plausible ranges. All possible matchings of the five high and low estimates (using R_c for consolidated holdings and R_s for scattered) yield 32 possible values for the probability of disaster on a consolidated holding and 16 possible values on a scattered holding. Table 15 arranges the values in a way that facilitates comparisons. Along a row in either the left (high d) or right (low d) panel the four variables that are involved in the calculation for both scattered and consolidated holdings (viz., s, R, D, and R_c or R_s) are the same. Along these rows, therefore, the probability of disaster for scattered and consolidated holdings can be compared.

Table 15. Probability of Disaster for High and Low Values of the Variables.

			High d			Low d		
		Scattered	Consolidated		Scattered	Consolidated	
			Low μ	High μ		Low μ	High μ
High R	Low Low s	.069	.078	*.064*	.013	.021	.018
	R_c or R_s High s	.147	.171	.154	.057	.085	.079
	High Low s	.127	.136	*.119*	.043	.057	.052
	R_c or R_s High s	.218	.224	*.209*	.119	.140	.131
Low R	Low Low s	.069	.129	.115	.013	.054	.048
	R_c or R_s High s	.164	.221	.206	.072	.136	.127
	High Low s	.133	.189	.174	.047	.104	.097
	R_c or R_s High s	.224	.274	.261	.129	.195	.187

Note: The equal probabilities for four of the cases of scattering are not misprints. They are equal qu fortuitously.

The 3 probabilities in italics are the only comparisons of 32 in which a consolidated holding is superior to a scattered one. The reader may judge for himself whether the events they have in common are likely to have occured together—R as high as .73, disaster as high as 60 relative to the mean, the coefficient of variation as low as .41 (except in one of the three), and income on a consolidated holding as high as 13 percent greater than on a scattered holding. The experiment demonstrates, in any case, that risk aversion is a robust explanation of open fields, insensitive to errors in its calculation.

OPTIMAL SCATTERING AND THE NUMBER OF PLOTS

Scattering was a Good Thing: so much is by now clear. Yet it is possible to have too much or too little of a Good Thing, scattering one's land in too many or too few plots, even though the gains in insurance on the whole outweigh the losses in efficiency. To put the point another way, it would be irresponsible to offer risk aversion as a large part of the explanation of scattering, urging that it replace inheritance customs or communal plowing in the usual tales, if risk aversion could not explain some significant part of the scattering actually observed. If a peasant scatters his 20 acres in 20 plots an explanation that implies he should scatter them in only 2 plots has drawbacks as a full account of his behavior. His behavior is, as it were, underexplained, leaving the puzzle of why he overinsured. An implication that he should scatter his acres in 200 plots would be equally embarassing, suggesting as it would that something in the argument was very wrong. The argument from partible inheritance has an affliction of this second sort, since once the logic of an increase in the number of plots per holding with each generation has been accepted it is hard to see why it would stop short of agricultural chaos. Of course, arguments can be patched up and made to hobble forward. One could patch up the inheritance argument by positing—albeit contrary to its egalitarian spirit—a limit to the sacrifices of efficiency that coheirs will make on the shrine of equality. If the risk argument underexplained scattering, predicting fewer than the observed number of plots, one could patch it up, too, rather more convincingly, by positing an uncertainty in the mind of the peasant about how risky in fact was his income, uncertainty driving him to overinsure. Peasants, after all, did not have at their disposal electronic computers and statistical theory (clumsy as even these elaborate tools of inquiry are), and they could not record their yields for future analysis, had such an absurdity occured to them, because they could not write. A cautious man facing danger is perhaps especially cautious when he knows little about the danger other than that it is there.

It will prove unnecessary, however, to invoke such arguments, plausible though they may be; when the hypothesis of risk aversion is put in further jeopardy, asking it to predict not only that peasants will hold a number of plots but also what number they will hold, it predicts the correct number. The first step in showing this somewhat surprising assertion to be true is to determine the actual number of plots on a typical peasant holding; the second is to determine the predicted number.

The evidence on the actual number of plots exists in a form that makes it convenient to break down the number into three components, the acreage of a typical holding, the number of nominal plots per acre, and the effective number of plots relative to the nominal number, the product of these three being the effective number of plots per holding. The acreage of a typical holding was discussed earlier, and the conclusion there, was that the typical acreage in two samples, one centered on the year 1250 and the other on 1600, was around 20 acres, give or take

5 acres, that is, somewhere between the acreage of a full and a half virgate. An "acre," of course, is in early times not always a statute acre. A more serious difficulty with using the evidence this way is that the units of farming ownership and of farming operation may well have been different, yet it is information ownership alone (or tenancy directly from the lord of the manor) that is most often contained in field maps and in lists of holdings. In the lists of tenants of a lord "the pattern of actual economic occupation of land might differ very widely from that of official tenancies" (Brooke and Postan, [eds.], 1951, p. 133). Subleasing and absentee ownership were common early and late in the history of the open field, both of which obscure the nature of the typical operating farm: a man who owned 20 acres could lease 30 more from three absentee owners with 10 acres each to form a large and relatively consolidated farm that would appear nowhere in the records. In Eversholt, Bedfordshire in 1764, for example, there were 59 freeholders or copyholders owning lands less than 50 acres, yet of these 33 were nonresidents who could not possibly have been operating their lands as farms (Fowler, 1928–36, pp. 37–53 of 1936). And holders were often women, who could be expected to rent out their land. Jane, Countess of Shrewsbury, owning a 6-acre freehold, probably did not follow the plow in the open fields of Laxton, Nottinghamshire in 1635. The purpose in mentioning this difficulty is to draw attention to it, not to solve it. The only easily handled lists distinguishing definitely between occupiers and owners (whether lords of the manor or not; though it was the lord, if anyone, who kept records in earlier times) are those of the Tithe Commissioners in the late 1830's, but the lists are ill-timed and ill-located for a study of open fields in the Midlands before the seventeenth century. In the absence of a systematic study of this and other sources one must hope, as do other students of the subject, that official tenancies are at least approximately to the point.

The evidence on the nominal number of plots into which an acre of land was divided, of course, has the same drawback. The records of the holding and transfer of land from which the number can be inferred—surveys, glebe terriers, and grants—do not distinguish ownership from control, and the same hope, pious homage to the gods of knowledge, is all that can be offered. The records are at any rate voluminous. To illustrate what can be done with them, consider those in H. L. Gray's pioneering work on *English Field Systems* (1915, pp. 23, 140, 307n, 309, 373, 389, 423–29, 549, and Appendix II, *passim*), namely, extracts from surveys of manors, church (glebe) holdings, and grants of scraps of land in 600-odd open field villages from the twelfth to the nineteenth century. Gray collected these as evidence of multiple field systems, not of scattering, and only about a fifth of the total mention the number of parcels. At Claydon St. Botolph, Buckinghamshire in the reign of Henry VIII, for instance, a terrier of a 26-½-acre holding mentions that in the three fields the land was arranged into 15, 11, and 15 parcels (p. 455). The 130 cases of this sort can be fashioned into a representative sample of open field agriculture in England as a whole. True, many of the cases are from counties such

as Dorset, Norfolk, or Herefordshire, outside the chief open field region; and the sources Gray consulted led to such peculiarities as an overrepresentation of Northamptonshire and Oxfordshire, and within Oxfordshire an overrepresentation of seventeenth-century glebe terriers. But the evidence is rich enough to allow for such biases. The cases outside the open field region, or later than the seventeenth century, can be omitted as tangentially relevant.[29] The ten cases of grants or surveys of demesne arable, usually in large blocks suitable to large-scale farming, can be omitted for the same reason.[30] The 96 that remain can be arranged as follows:

Table 16. Parcels Per Acre, 12th to 17th Century.

	1100–1400	1401–1700
Oxfordshire	1.42	1.03
n (standard error)	10(.19)	22(.11)
Northamptonshire	1.99	1.36
n (standard error)	14(.10)	6(.24)
Others	1.30	1.59
n (standard error)	23(.19)	21(.12)

Note: "Others" are in both periods Beds, Berks, Bucks, Cambs, Herts, Leics, and Yorks; in 1100–1400 also Hunts, Lincs, Notts, Warwicks; and in 1400–1700 also Wilts.

Any reasonable weighting of the sample would put more weight on "Others" than on Oxfordshire and Northamptonshire, both of which diverge fairly sharply from the rest in both periods. Weighting the three by their acreage enclosed by act of Parliament, for example—reasonable enough considering that the object is to describe the typical village in open fields—the average in the first three centuries is about 1.4 parcels per acre and in the second about 1.5, suggesting that there is no strong trend.[31] The unweighted average of all 96 cases is 1.42 and the median 1.45; it would exaggerate slightly, if anything, to say that a 20-acre holding was scattered in 30 or so parcels.

Many of these parcels, however, were clustered. When one foreign half-acre strip separates three of Christian Coxe's strips in Llancadle, Glamorgan in 1622, it is clear that no motive of risk aversion (or for that matter egalitarianism or strictly partible inheritance) could have been at work preventing consolidation, for it would have been cheap to trade lands to form a consolidated plot (or to lay them out together at the time of inheritance), were there something to be gained. It is equally clear, however, that little was to be gained; neighborhood effects are comparatively easily handled when there is only one neighbor, subleasing would be

natural, joint fencing of the three Coxe plots and the one foreign plot would be cheap (and was in fact done in some villages), transportation among the three plots would be trivial. In short, for most farming purposes the three plots count, though they were not counted, as one. The difficulty is that of deciding what criterion, necessarily somewhat arbitrary, should replace the equally arbitrary but less illuminating criterion of one nominal plot counted as one effective plot. If one adopts the criterion for Llancadle that a collection of plots is to be counted as one when no piece is separated from another by more than one other owner and no part of any piece is outside a radius of 150 yards from the center of the effective plot, Coxe's 27 distinct nominal plots reduce to 12 effective plots.[32] Adopting a similar criterion for Laxton, Nottinghamshire in 1635 gives the results in Table 17.

Table 17. Nominal and Effective Numbers of Plots for Six Men at Laxton

Holder	Open Field Acres	Number of Plots Nominal	Number of Plots Effective	Effective/ Nominal
Tho. Tailer, Sr.[a]	48	78	48	.62
Tho. Hassard[a]	34	73	44	.60
Edw. Kelsterne[a]	28	45	33	.73
Hugh Tailer[b]	25	44	31	.70
John Chapell[c]	24	23	19	.83
Robert Rosse[a]	14	23	14	.61
				Average .68 (standard error, .04)

[a] = Tenant
[b] = Tenant of the Chantry
[c] = Freeholder

Source and Notes: Orwins, 1938, pp. 137–42 and Part III (Survey and Maps). The calculation excludes closes and town land. The scale is not given in the Orwins' maps and had to be inferred from acreages. Users of this pathbreaking and much—perhaps over—used book may wish to know that the map of the town and East Field is at 257 yards per inch, the West Field at 230, the Mill Field at 284, the South Field at 232, and Laxton Moorhouse at 264.

It would not be surprising to find, therefore, that the number of effective plots was two-thirds or so of the nominal in open field England, which implies, together with the figure of 1.5 nominal plots per acre, that the number of plots was roughly equal to the number of acres in a holding. On a 20-acre holding, then, the number of plots to be predicted by risk aversion is about 20, or 6-⅔ on average in each of the three fields of a village.

THE PREDICTED NUMBER OF PLOTS

The number predicted by the theory is the number of plots, N, that makes the probability of disaster as low as possible. On the one hand a larger N reduces the probability by reducing the standard deviation of income, σ (which is dependent on N); on the other hand it raises the probability by reducing the average income achieved, μ (also dependent on N), bringing it closer to the disastrous level of income, D. Mathematically speaking, σ and μ are functions of N, and the object of the peasant is to choose the N that minimizes the distance from disaster that μ is in terms of σ, namely, $\{ (\mu(N)-D)/\sigma(N) \}$. The way that σ varies with N is already known, namely:

$$\sigma(N) = As[\frac{1 + (1 + R)N}{N}]^{1/2}$$

in which A is the acreage in a holding, s is the standard deviation of the yield on an acre of one type of land, and R is the correlation of yields between types. The difference between this equation and the one used repeatedly above is that here it is expressed in standard deviations rather than in coefficients of variation. For this reason A appears in it. If the average yield on an acre of a single type is called q, the yield of a holding of A acres will be, obviously, Aq, the coefficients of variation are therefore σ/Aq and s/q, and putting these expressions into the earlier equation produces the equation here, since q cancels out.

The way that the average yield on the entire holding, $\mu(N)$, varies with N is at choice, and is the only novel ingredient in the argument. A simple and plausible choice is $\mu(N) = AcN^{-\epsilon}$, in which c is a number setting the scale that reflects the productivity of the techniques, tools and labor used on the holding, and ϵ is the percentage rate at which yield falls with each percentage increase in the number of plots. The same percentage increase in N, whether from 3 to 6 or from 15 to 30, say, reduces output further by the same percentage. Another simple choice, a straight line relationship between μ and N, is less plausible because it implies that the same absolute increase in N, whether from 5 to 6 or from 29 to 30, reduces output by the same absolute amount, even though the additions to distinct neighbors or convenient paths through growing crops or travel time to visit a scattered holding fall as N rises.

The distance from disaster to be minimized, then, is:

$$\frac{\mu(N) - D}{\sigma(N)} = \frac{AcN^{-\epsilon} - D}{As[\frac{1 + (1 - N)R}{N}]^{1/2}}$$

When D is replaced by $d\mu(1)$, where d is the percentage that disaster is of the maximum attainable average yield (at which $N = 1$), and terms are collected the result is:

$$(\frac{c}{s}) \ \frac{N^{-\epsilon} - d}{[\frac{1 + (N - 1)R}{N}]^{\frac{1}{2}}}$$

Since the term c/s is constant, the whole expression will be at a minimum with respect to choices of N when the other term is. And since this other term is a quotient it will be at a minimum when the rate of change of its upper part with respect to N is equal to the rate of change of its lower part. The rates of change are:

$$\text{Upper: } -\epsilon(\frac{N^{-\epsilon}}{N^{-\epsilon} - d})$$

$$\text{Lower: } -1/2[\frac{1 - R}{1 - (N - 1)R}]$$

When ϵ is small (it is, as will be shown in a moment), $N^{-\epsilon}$ is approximately equal to 1.0. Using this approximation, setting the two expressions equal to each other, and solving for N leads to a simple prediction:

$$N \cong (\frac{1 - R}{R}) \ [\frac{1 - d}{2\epsilon} - 1]$$

The clearest way of applying this equation is to a single one of the three open fields of a village, in which there were on average 6.66 of the 20 plots on a typical holding. The question is whether or not the equation implies an N of about 6.66. It was shown earlier that on a single field R was .60.[33] The appropriate value of d, the disastrous level of output relative to the best attainable average, is below the earlier appropriate value for all crops together, .50, for two reasosn. First, the value .50 is disaster relative to the average output actually achieved on a scattered holding, not, as defined here, relative to the higher average (10 percent higher, in fact) attainable on a fully consolidated holding. On this account the denominator used to calculate d must be higher. If wheat contributes on the average 33.3 units of income to the average income of 100, the denominator should be $(1.10) (33.3) = 36.6$, not 33.3. Secondly, because a given degree of failure in one crop of three is less serious (in view of the good chance that the other two crops will offset it) than is the same degree of failure in all three at once, the numerator is smaller. When the correlation of wheat with other crops was only .29, as it was, a peasant would for this reason look with equanimity on a crop of wheat 50 percent below normal, that is, a crop of $.50 (33.3) = 16.6$. A numerator of 16.6, then, is too high a level. The

correct level is the answer to the following question: what, on the average, is the output of, say, wheat at which disaster, considering the various possible outputs of barley and oats, just strikes? Put another way the question is, what output of wheat corresponds on the average with the margin of disaster, i.e., an output of all crops added together just below 50? It was determined earlier that the typical coefficient of variation of wheat, barley, or oats after scattering within one field was .48 in English open fields, implying a standard deviation of 16 relative to a mean of 33.3 for a single crop; and that the typical correlation between any two crops was .29. The question posed can be answered by inserting these values into a trivariate normal distribution and calculating the frequency with which various outputs of wheat are associated with the narrow attainment of disaster overall. Weighting the outputs of wheat by these frequencies gives an expected value for wheat (or any one crop) of 12.6: this is the numerator. The appropriate value of d in one crop, then, is $12.6/36.6 = .34$.

The remaining element in the equation is ϵ, the elasticity of output with respect to the number of plots. Like d, ϵ is calculated by looking at the facts already established in another way. Output increased by ten percent when a holding scattered into twenty plots was consolidated into one. In terms of the relationship between average output and N, with N_B the number before, and N_A the number after consolidation:

$$\frac{AcN_A^{-\epsilon}}{AcN_B^{-\epsilon}} = \frac{(1)^{-\epsilon}}{(20)^{-\epsilon}} = 1.10$$

Solving for ϵ after taking logarithms implies an ϵ of .032. That is each doubling of the number of plots in each of the three open fields of the village (1, 2, 4 and so forth, producing a total number of plots of 3, 6, 12 and so forth) reduced average output by about 3 percent.

The Lord apparently favors this enterprise, for the predicted number of plots in a single field is 6.2, very close indeed to the observed number, 6.66:

$$N = (\frac{1.0 - .60}{.60}) \ [\frac{1.0 - .34}{2(.032)} - 1.0] = 6.2$$

What the Lord giveth, however, He can take away, by varying the parameters, and the exactness of fit between the theory and the facts is not to be taken too seriously. The predicted N varies in the following way with choices of d and ϵ around the best estimate (given $R = .60$):

Table 18. Sensitivity of Predicted N
to Alternative Values of d and ϵ.

		value of d		
		.40	.34	.28
value	.020	9.3	10.0	11.0
of ϵ	.032	5.6	6.2	6.8
	.040	4.3	4.8	5.3

These are, to be sure, large variations in the parameters, but it is nonetheless worth bearing in mind that at their extremes they imply that a 20 acre holding in three fields could be scattered in anything from 13 ($= 3 \times 4.3$) to 33 ($= 3 \times 11$) plots. What survives even this degree of scepticism, however, is that the equation does predict the correct order of magnitude.

It succeeds in predicting the facts in certain other ways as well. It predicts, for example, that peasants holding larger acreages and being therefore further from the margin of disaster would have lower d's and larger numbers of plots, as they did, although fewer plots per acre, as they also did.[34] True, the prediction that scattering would rise as d fell fits poorly with the drive to enclose when, in the seventeenth and eighteenth centuries, d became low. Yet the very reduction of risk that made d low on the eve of enclosure, particularly for large farmers (who were in fact the most eager to enclose) made the fear of ruin less relevant; when ruin becomes a remote possibility—not one year in 13 but one in 50, say—the fear of it diminishes. And the rise during these centuries in the uniformity of yields (R) and in the gain to be had from enclosure (ϵ), both of which would work to reduce N whether or not the distaste for variability took the form of safety first, fit well with the history of enclosure.

ALTERNATIVE INSURANCE

Showing that scattering was efficacious insurance does not show that the insurance achieved suffices to explain scattering, although it makes the proposition appealing. In an extreme and monocausal form well beyond the ambitions of this essay the proposition would be a syllogism: medieval English peasants wished only to reduce hazard; in the Midlands in medieval times only scattering of plots would reduce hazard; therefore, medieval English peasants in the Midlands would always scatter their plots. A comparably extreme syllogism for the main alternative explanation would be: medieval English peasants wished only to achieve equity of inheritance; in the Midlands in medieval times only scattering of plots would achieve equity of inheritance; therefore medieval English peasants in the Midlands would always scatter their plots. What makes the two syllogisms extreme are the words "only" and "always." Disproving the extreme form of

each step does not reduce more moderate forms of the arguments to rubble. If medieval peasants wished also to eat well in most years and to enter the Kingdom of Heaven it might still be true that their wish to reduce hazard or to achieve equity of inheritance was powerful. Yet comparing each step in the extreme forms is illuminating. If one had to choose between two simple characterizations of peasants (one does not have to, of course), that they were cautious or that they were egalitarian, which would one choose? Enough has been said here to establish that they were very cautious, with good reason. In the essay mentioned earlier (McCloskey, 1975a) it was argued that they were not very egalitarian, the chief evidence being that the distribution of land was inegalitarian, that inheritances of land were unequally distributed between sons and daughters, and that in any case inheritances in the Midlands were not in fact divided equally among sons. In the same essay it was argued that the other step in the extreme form of the syllogism—that only scattering would achieve equal inheritances—is still less plausible. Equality could have been achieved without the gratuitous burden of scattered plots, by dividing holdings instead of each plot in a holding, by making up inequities of land with more divisible assets, and, most fundamentally, by exchanging ill-situated plots in the market for land, which was cheap and active from the thirteenth century onwards. But the parallel step in the risk syllogism—that only scattering would reduce hazard—might face a similar difficulty, namely, a substitute for scattering as a means of achieving insurance. Did alternative and cheaper insurance exist?

In its strict definition it plainly did not. Insurance against fluctuations in the price of agricultural products has become available in modern times in the form of organized forward markets, and there is some hint in the historical record of forward selling of crops by the larger farmers. Speculative markets on any substantial scale, however, appear to be a nineteenth century innovation. Cheap insurance against fluctuations in yields (as distinct from prices) is to this day seldom available, notwithstanding the complaints of observers of the agricultural scene that farmers are driven by its absence to expensive methods of self-insurance. E. J. Russell, the director of the Rothamsted experimental farm, remarked in 1924 that "at present crop yields are uninsurable in England at any reasonable premium; if, however, there existed trustworthy tables of expectancy of crop yield, crop insurance would become as readily amenable to business management as life insurance" (Russell, 1926, delivered 1924). He was perhaps underestimating the other obstacles to the success of such a scheme, namely that farmers would take less care to avoid a bad crop when their return was guaranteed (less likely, obviously, with life insurance) and that a farmer who knew his crop was going to be bad would rush to buy insurance (as a sick man would buy life insurance). Writing in 1952, Earl Heady noted that although hail insurance had been available in the United States for many years (it was available in England from around the turn of the century), general crop insurance had been available

only since 1938, and then only for a few crops. He argued that the difficulty was self-selection of poor risks in the absence of full knowledge by the insurors: a winter wheat producer on the Great Plains, for example, could predict his yield by the amount of moisture his crops had gotten in the previous autumn (Heady, 1952).

Formal insurance, however, is not the only way of insuring against disaster. Peasants could, and did, hold assets other than growing crops which, if their yields were not highly correlated with the crop, would serve to reduce the variability of total income. As was argued earlier, diversification of this sort became important in early modern times. A medieval peasant was less well placed to take advantage of a diversified portfolio of assets. To be sure, his growing crop was not the only productive asset he had: he had his lease, his labor, and his agricultural capital, above all draft animals, which in a bad year he might sell. Yet his labor would be worth little if the bad year were general, and selling his lease or his agricultural capital in a bad year would make the following years bad as well. The plow team and other moveable goods a peasant might have were in any case hazardous themselves, subject as they were to seizure and taxation. He could save money. In the thirteenth century Walter of Henley gave this advice to lords of manors anxious to improve themselves: "If you may your lands amend, either by tillage or by a stock of cattle or by any other provision above the yearly extent, put that overplus into money, for if corn fail or fire do happen or any other mischance then will that be somewhat worth to you which you have in coin" (Oschinsky, [ed.], 1971, p. 309, sixteenth-century translation, spelling modernized). The lord of the manor might follow such advice, rich and secure as he was, without his peasants being in a position to do so as well. Money was in any case a bad store of grain value. With poorly developed markets and precarious yields ten bushels given up for silver in a good year might well buy only five bushels for a peasant's table in a bad year.

The peasant could save grain itself, and did. What matters for insurance against a harvest failure, however, is the store of grain that survived a year of eating and replanting, the carryover. At the end of the seventeenth century, in an England enriched by a century or more of agricultural progress, Charles Davenant estimated the carryover at "not above four months' stock in an indifferent [i.e. average] year, which is but a slender provision against any evil accident" (Thirsk and Cooper, [eds.], 1972, p. 814), and made the perennial suggestion of constructing public granaries. In the middle of the sixteenth century the City of London, forward in all things, aimed to keep 5000 quarters of grain at the London Bridge House for this purpose (Ashley, 1914, II, p. 25). But it would have found the purpose difficult to achieve; at two-thirds of a quarter of grain per head per year (a low estimate) and with 50,000 or so Londoners (another low estimate) 5000 quarters would have been only 15 percent of minimum annual consumption, and less of the average. Storage was expensive, both in interest foregone and in spoilage: the wide flunctuations in prices over the harvest year and from harvest to harvest testify to this, as do the primitive techniques of storing grain in a wet

climate and the high interest rates of the age. The stores of monks and burgers, in any case, are not necessarily stores available in a bad year to the peasant: he must have his own carryover, and probably had a trivial one. Judging from yields on the Bishop of Winchester's estates, the years leading up to the bad harvest of 1315 were reasonably good, yet by the spring after the harvest prices had doubled in England, and in Ypres (where there are statistics; the famine was European in extent) the death rate rose in the spring and remained high until the new harvest (Lucas, 1930. In Carus-Wilson, [ed.], II, pp. 55, 67).

If the peasant could not rely on borrowing, as it were, from himself, he could borrow from others. A market in loans is from one point of view a substitute for scattering. From another point of view, however, it is a complement of scattering, for the heavy indebtedness already contracted by peasants to pay entry fines, dowries and exceptional taxes (see, e.g., Duby, 1968, pp. 252–54) would make a method of avoiding still further indebtedness especially attractive. Although it is difficult to penetrate the veil thrown across the subject by the hostility to usury, the interest rates charged appear to have been very high (Pollock and Maitland, 1898, I, pp. 469, 473 and II, p. 225). And an interest rate of 40 percent on money loaned in a bad year would translate into a still higher rate in terms of grain when the loan was repaid: if the price of grain fell 50 percent between the bad year and the next, the annual rate in real terms would be 180 percent. A less formal alternative, presumably free of interest, is charity, personal or institutional. Yet the volume of sermonizing in the Middle Ages on the virtue of charity is testimony less to its abundance than to its scarcity relative to the precepts of Christian ethics. The church itself was supposed to turn back a good part of its income to the poor, but, notoriously, did not.

The substitutes for scattering as a means for achieving insurance, then, are unimpressive, less impressive than the substitutes for scattering as a means for achieving, say, equity of inheritance. As was pointed out earlier, of course, the growth of a market in cheap loans or the enrichment and diversification of agriculture does figure in the story, chiefly after the sixteenth century. In some places, earlier, it might account for the erosion of open fields, as in the Southeast of England, exposed early to the markets of London and of the northwest coast of Europe generally. It is undoubtedly false, to give again the extreme version of the proposition, that in the Midlands of England in medieval times *only* scattering of plots would reduce hazard. Yet between this extreme proposition and a more moderate one there is ample ground for believing in the efficacy of scattering for insurance.

*   *   *   *

A satisfactory explanation of the English open field must be an explanation of its persistence and decline, since the paucity of birth records of the system leaves room for unrestrained speculation on its origin. Following the principle that it is the knowable that one should seek to know, therefore, the question is: why did

open fields persist from the twelfth to the nineteenth century in some places in England and disappear in the seventeenth and eighteenth centuries in most? The guiding principle in answering this question has been to ask in turn why an ordinary peasant would want to scatter his plots, for it was he—or so it is assumed in this study and in similar studies by others—who determined the usual geography of holdings. The answer offered here is that he scattered not to equalize inheritances or allotments of new village land but to insure himself against the hazards of farming before the Agricultural Revolution. It might be argued, indeed, that the alleged egalitarianism was merely a manifestation of a desire for scattered plots and the insurance they provide. In any case insurance explains the gross facts of the persistence and decline of scattering; it predicts some scattering and the amount of scattering that in fact occured; and it fits well with the view of medieval village life, long the orthodox view, that attributes self-interest as well as fellow-feeling and conservativism to medieval peasants. Peasants were conservative, to be sure, but not pointlessly so: a man is not a fool to insure himself against disaster by scattering his plots of land.

FOOTNOTES

This is a draft of a chapter in a book on *The Enclosure of English Open Fields*. I have received comments from many people, and pledge full acknowledgment in the book. I must here thank by name, however, Stephano Fenoaltea of Amherst College, whose voluminous criticisms, many of them embodied in his ''Risk, Transaction Cost, and the Organization of Medieval Agriculture'' (1974), have been a great stimulus to thought. The research was supported in part by a grant from the National Science Foundation.

1. The usual word for scattering in the literature, incidentally, is ''fragmentation.'' I avoid it because it is also used for small, as distinct from scattered, farms.

2. Thompson (1963), pp. 8, 170–73. Compare Euthymios Papageorgiou in Parsons, *et al*. (1956), p. 546: ''The fragmentation is not always a disadvantage, however. Where fruits, vegetables, and flowers are farmed intensively, a moderate degree of fragmentation diminishes the risk of damage from frost.'' In the same volume, p. 536, J. Roche makes a similar point about scattering of plots in France for those crops. And on p. 559, Setsuro Hyodo makes it for agriculture in general in Japan.

3. Personal correspondence. Thomas first heard this from farmers in the Southwest Dacca region, but later confirmed it for East Pakistan as a whole.

4. Beidelman (1971), p. 18; Netting (1972), p. 134; Johnson (1971), pp. 69–72. Further evidence on Tanzania (collected by geographers) appears in the articles by Hawkins, and by Heijnen and Kates, in White, [ed.], 1974.

5. Thomas Hitt in 1761 drew the contrast in detail with light sand or chalk soils, remarking that ''two dry days render them in good order for plowing and harrowing.'' (Jones, 1964, p. 113.) Compare H. David, *Complete English Farmer* (1771), pp. 85–86, who warns of a common soil in England that ''were it to be ploughed in a rainy season . . . would cling like mortar; and if sowed in such a situation, would produce little or no increase.'' (See also pp. 100, 165–72.)

6. The estimate is calculated from the median moveable wealth per acre among the eleven farmers holding 15 to 45 acres for whom the recorded acreage of fallow indicates that acreage in fallow is not being ignored. Given in F. W. Steer (1969), p. 52. The dates of the eleven range from 1666 to 1743.

7. The argument is widely applicable. M. I. Finley argues that in the fifth and fourth centuries B. C. alternative employment in the navy was ''the key to Athenian freedom from agrarian troubles,'' in contrast with the more usual state of affairs for free peasants: ''the ancient peasant was always at the margin of safety.'' (1973, pp. 107–108).

8. Ballard (1908), p. 459; see also Slicher van Bath, 1963, pp. 32, 37. The yields are net of tithe. Ballard records that the customary acre was 90 to 120 poles, or about two-thirds of a statute acre.

9. Subtracting by one is only an approximation because the amount of seed set aside could vary, although it would not vary if the same output on average was wanted year in and year out and if exceptionally bad crops did not require eating some seed. With the raw data from the issue of the grange one could make the calculation exactly.

10. Another consequence of low yields per bushel of seed in the Middle Ages, incidentally, is that investment in seed was a high percent of gross output. Were the yield of wheat 4.0, a quarter of the harvest would need to be invested each year in seed. Savings rates of 25 percent belie the customary assertion that peasants, medieval or other, save little or save only in the form of cathedrals and gold, not in productive investments.

11. Page (1934), pp. 329–30. The yield of the year 1394 is missing. The demesne was held in strips intermingled with those of the tenants, not in a compact block (p. 79).

12. What follows is merely a rewriting of Fama and Miller (1972), pp. 253–55.

13. How trivial may be judged as follows. Taking the standard deviations of the yields of wheat, barley and oats, at values consistent with medieval experience (the averages observed in one sample of Winchester yields 1335 to 1349, in fact), namely .38, .40 and .60, and the correlation coefficients of wheat-barley = .38, wheat-oats = .27, and barley-oats = .42 (the averages observed within each demesne in the same sample), the σ implied by the full equation, (1), is .350; that implied by the approximation, (2), when the average R and the average s (not average s^2) are arithmetic averages, is .348.

14. The equation is not defined for $[1 + (N - 1)R] < 0$, e.g. N = 3, R = -1, since the square root of a negative number is imaginary. It is clearly impossible to hold more than two types, each of which is perfectly inversely correlated with every other.

15. Haldane (1941–42), pp. 233–34. The assumption of normality is treated later, and verified.

16. Titow (1972), p. 4, simple average of wheat, barley and oats. Allowing for the greater weight of barley in the peasant's output than the simple average assumes (1/3) changes the average little.

17. The procedure is to simulate the variability of $I = Q - (M/a)Q^b$, when the coefficient of variation of Q is .35, a is set at 1 (to set the scale), M is chosen to take half the value of the crop at the average values of Q and P, and b is $-.5$.

18. E.g., Goubert (1970), p. 217, speaking of the ''disastrous'' French crop failure in 1693. See Davenant's comment on this episode in Thirsk and Cooper, (eds.), 1972, p. 813, in which the figure of one-half is used.

19. Postan (1966), p. 622; Titow (1969), p. 89. These are for a three-field system.

20. Postan (1966), p. 619. In Tawney (1912), pp. 64–65 there is a similar table of customary tenants for the late fifteenth through the early seventeenth century. In it holdings below 10 acres account for 16 percent of all land in holding up to 40 acres (a reasonable limit for farming without hiring outside laborers).

21. Darby. In Darby, (ed.) (1936), p. 196n. Cf. Genicot's estimate, apparently based on

chronicles, of 18.2 years in Languedoc in the fourteenth and fifteenth century (14.3 years in the fourteenth century alone). In Postan (ed.) (1966), p. 673.

22. Fussell, (ed.) (1936), *passim* (e.g. pp. 5–6, 184). The south part of the village was on the edge of the Berkshire Downs and could not therefore have supported hay. The north part of the village close to rivers was about a mile square.

23. Or more, in view of the errors in measurement of d (the distances between the wheat crops is not the same as the distances between churches). Reversing the regression implies an upper bound on the coefficient on d of .22.

24. That the difference is negative (rather than zero, as one would expect) when $d = 0$ should not be troubling, for the intercept is an extrapolation beyond the range of the data. To put it another way, the linear specification could easily be wrong for small distances, the true relationship flattening out at distances below the observed minimum (1.5 miles). The r^2 of $R_w - R_b = .008d^{2.72}$ is in fact a little higher, .65.

25. A minor point should be mentioned here. The calculation assumes that the coefficient of variation can be applied to the average income on a consolidated farm (110) to yield the standard deviation. This is true only if the standard deviation rises for higher averages (technically speaking, only if the distribution of yields exhibits heteroscedasticity). It does. For 22 randomly selected series of wheat yields on the Bishop of Winchester's estates 1335–49, the correlation of the yield and the standard deviation was .78 (significantly different from zero at conventional levels), while the correlation of the yield and the coefficient of variation was −.23 (insignificantly different from zero).

26. Cf. Jones (1964), p. 50: "Every farmer is in a state of constant uncertainty and if he is sensible will take costly measures to insure his own business against loss: the chances that his personal output will be depressed are much higher than the chances that the weather will depress the total output of agriculture."

27. Many of the alternative hypotheses, incidentally, share this difficulty, because many of them suppose that peasants were egalitarian. One cannot test the equality of inheritances or plowing dates or intakes from the waste without knowledge of the second as well as the first moment of the relevant distribution.

28. For example, s is distributed as a chi-square with 14 degrees of freedom, from which the high and low averages on either side of the median can be calculated. The procedure for the R's is similar, using Fisher's z.

29. The omitted counties are Norfolk (12 cases, all eighteenth century), Herefordshire (8 cases, all nineteenth century), Gloucestershire, Somerset, Middlesex and Essex. They have a noticeably lower number of parcels per acre on average (around 1.0) than do the remaining counties.

30. Once again, these have a low number of parcels per acre (that is, a higher number of acres per parcel), namely .39.

31. The acreages enclosed by act are given in Slater (1907), pp. 141–47. Not all open fields were enclosed by act, but the records of the many that were not are sparse.

32. The map is reproduced on pp. 504–505 of Davies. In Baker and Butlin, (eds.), 1973. Coxe was a copyholder of about 40 acres.

33. Because of the simplicity of the relationship between N and R the equation works poorly for extreme values of R: $R = 0$ implies infinite N; $R = 1$ implies zero. So long as the assumption of constant elasticity is reasonable in the range of R actually observed, however, this feature is not more troubling than are parallel features of, say, demand curves with constant elasticities.

34. As acreage increases average income rises, reducing d at the same rate. From the equation predicting N one can show that the rate of change of N (taking ϵ to be approximately zero, as it is) is $N^* = -[d/(1 - d)]d^* = [d/(1 - d)]A^*$, from which follow the assertions in the text.

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