

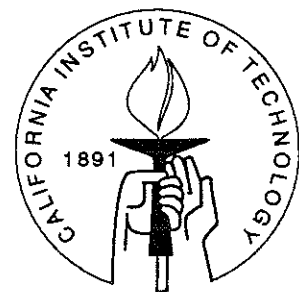
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New Evidence for an Old Controversy: Scattered Landholdings and Open Fields

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Abstract

We bring new evidence to bear on McCloskey's argument that farmers in the open fields reduced risk by scattering their land holdings. The new evidence is the grain output from a number of plots of land in two French villages, Onnaing and Quarouble, during the years 1701–1790. When combined with prices and wages, the output figures provide financial returns for each plot of land, and financial theory then allows us to construct land portfolios that minimize portfolio variance for a given mean return. The virtue of using returns (rather than simple output correlations) is that the returns take into account the price fluctuations farmers encountered. They also allow us to distinguish the benefits of scattering from those produced by crop diversification and they do so with greater accuracy than the output figures. In the end, the returns demonstrate that scattering of land holdings provided relatively little insurance. The real reduction in risk came not from scattering but from the diversification across crops inherent in the three-field system.

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1 Introduction

In a celebrated series of articles, Donald McCloskey has sought to elucidate the most puzzling mystery of medieval and early modern agriculture—the scattered holdings that prevailed across the open fields of northern Europe. While historians had long invoked population growth, inheritance laws, the difficulties of plowing, or a primeval spirit of egalitarianism to explain why peasants dispersed their holdings throughout the open fields, McCloskey argued that the practice served as insurance against agricultural risk. In the jargon of finance, the scattered plots of land were a diversified portfolio that protected a peasant against weather, pests, and natural disasters. A strip of land in a damp hollow might bear fruit in searing drought, while one on a sunny hillside might do so in frost or flood. Still others might let crops survive locusts or hail. For a cautious peasant, dispersing plots of land must have seemed a better strategy than risking hunger when the harvest dipped perilously low.¹

The virtue of McCloskey's argument is that it accounts for a major obstacle to technological change. To be sure, the open fields were far from universal in Europe, particularly before the later Middle Ages, and the rigidity of open field farming should not be exaggerated. Grain yields did improve on the open fields; farming practices on them—contrary to what is often assumed—were not always hemmed in by unyielding regulation.² Even

*We wish to thank Lance Davis for his comments.

¹McCloskey 1972, 1975, 1976, 1989, 1991.

²Recent work by both historians and archaeologists suggests that although the scattered fields and open field farming date quite far back in some places (as in parts of England) they were by and large an invention of the later Middle Ages; even then they were unknown in much of Europe (Rösener [1986] pp. 57-61, 130; Chapelot and Fossier [1985] pp. 50, 170-174; Abel [1978] pp. 19-20, 73-83). Grain yields apparently rose on English open fields (Allen and O Grada [1988]; Yelling [1977] pp. 146-173). The yield figures here, though, are somewhat controversial; for the controversy, see Allen [1988], Overton [1979, 1984], Turner [1982, 1984]. As for the regulation of open field farming, it is often assumed that the grazing rights and the communal crop rotations associated with the open fields restricted innovation, but such was not the case, for example, in much of France; see the masterful discussion in Meuvret [1977-88] (2 (*Texte*): 11-46). Moreover, it was quite possible to have open fields and scattered holdings without either grazing rights or communal crop rotations: Thirsk [1964].

so, there is no denying that the scattered plots exacted a heavy toll, particularly in the eighteenth and nineteenth centuries. They exacerbated strife between neighbors and forced farmers to adopt defense practices that left everyone worse off. They bred strategic behavior that blocked improvements such as drainage, and they so complicated the tasks of planting, grazing, or harvesting that new crops and innovative practices were discouraged.³

In a discipline as contentious as economic history, it is perhaps not surprising that McCloskey's argument, despite its merits, has never convinced all the practitioners. Scholars trained as traditional historians have long remained skeptical, and among those schooled as economists, several (most notably Stefano Fenoaltea) have devised intriguing alternative explanations.⁴ The resulting controversy has never died down, in large part because both McCloskey and his critics lacked the sort of evidence that would settle the debate. They lacked it for an obvious reason: it seemed impossible to find. Yet the necessary evidence does exist, and we have found it, or at least something close to it. We can therefore put McCloskey's reasoning to the test and do so with tools more powerful than those McCloskey himself employed.

2 The Evidence from Onnaing and Quarouble

McCloskey's story revolves about the variance of grain yields, grain being the major crop on the open fields. Bad weather, pests, and natural disasters caused yields to swing wildly, but a peasant could reduce the variation by scattering his holdings to take advantage of microclimates and local differences in the incidence of plant disease and other calamities. Conceivably, he might even be able to reduce the variance of his grain output to that of the village as a whole.

For this story to work, though, requires that the yields on separate strips of land in the village not be too closely correlated, for if the yields on separate strips do rise and fall together, then scattering provides no insurance and no compensation for the burden of farming dispersed holdings. Nearly the whole argument, at least in McCloskey's formulation, therefore depends on the correlation between yields on different plots within the typical open field village. McCloskey maintains that this correlation –call it R – was, for typical plots, probably about 0.60, but he admits that the evidence is far from perfect.⁵ Since medieval and early modern farmers did not record the grain produced on each individual strip of land, McCloskey is forced to rely on evidence from nineteenth-century

³See Ault [1972]; Meuvret [1977-88], vol. 2 (*Texte*): 38, 107-108; and Hoffman [1988]. There is abundant evidence of the disputes brought on by scattering in nineteenth-century France, where, because the loser paid the winner's legal fees, the costs of litigation could exceed the value of the land fought over: Hottenger [nd], [France] Ministère des finances [1891], and Boulay [1902].

⁴For one historian's skepticism, see Wilson [1977], p. 37. For Fenoaltea's views, see his most recent contribution to the debate (Fenoaltea [1988]), which contains an excellent summary of the literature on the open fields.

⁵McCloskey [1989], pp. 39–43; [1976], pp. 145–53.

agronomy experiments and from the records of manorial farms in order to estimate R . Neither source is entirely reliable.

The agronomy experiments correlate yields on individual plots of land, but since they involve late nineteenth-century methods of cultivation, they make for a rather strained comparison with medieval and early modern farming, as McCloskey himself acknowledges. If one were to overlook such difficulties and simply extend the experimental correlations back into the past, then R would be perhaps 0.80 or so, a dauntingly high correlation. McCloskey argues, not unpersuasively, that this is merely an upper bound for R , because the experimenters carefully controlled the methods of cultivation and thereby eliminated sources of variation among plots. But the variation among the plots may also have been reduced by the very different agricultural techniques utilized in open field farming.⁶ If so, then R may have indeed been as high as .80.

The evidence from the manorial records is also imperfect. It concerns, not the individual strips of land within a single village, but entire farms located in separate villages. The problem here is the distance between the farms: because they lay in separate communities, the distance between them was far greater than that between typical strips in a single village's open fields. Unfortunately, the distance and the output correlation are related. As the distance between manorial farms increases, the output correlation falls; presumably, the correlation R between typical strips does the same. McCloskey is therefore forced to extrapolate from the distance-correlation relationship for manorial farms in order to estimate R for strips, but even though he restricts himself to nearby farms, he is still dealing with properties that are much further apart than the strips in an open field village. His extrapolation is thus quite risky; as he himself admits (McCloskey [1989] pp 40-41), the 0.60 estimate for R that he derives from the extrapolation "may be too low to represent the correlation facing a peasant in one open field in a village."

What we need, obviously, are yields from plots of land that are much closer together—precisely the evidence that seems impossible to find. Yet such evidence does exist and we have located it, surprisingly, in published documents. It comes from the unusual tithe records unearthed by Morineau for his study of the evolution of French grain yields.⁷ The

⁶McCloskey [1989] (pp. 39-40). The common practice of sowing maslin (mixed rye and wheat) was but one technique of traditional open field farming that reduced the variation in yields among plots. One reason farmers planted maslin was that the sturdier stalks of rye prevented the wind and rain from beating down the fragile wheat. The maslin would therefore diminish yield variations due to differences in exposure among plots. See Meuvret [1977-88], vol. 1(*Texte*): 148, and *passim*, for this and other techniques of plowing, sowing, and harvesting that might have also lessened the variation among plots.

⁷Morineau [1971], pp. 32-35, 97-162. His evidence comes from the Archives départementales du Nord in Lille [henceforth AD Nord], 4 G 3456-3457, 5379-5731, which we have also examined. Though rare, similar sources can occasionally be found in tithe records and in the documents concerning seigneurial dues such as the champart, but they always seem to lack the virtues of Morineau's documents. Whereas his sources track grain yields on separate parcels of land for centuries, most other records stop after a short time or make it exceedingly difficult to follow the yield on the same parcel of land. That was the case, for example, with the champart records in the Archives départementales du Calvados (Caen), H 2873- 2874, and with those in the Archives départementales des Yvelines (Versailles), 55 J 348-351. Other sorts of documents that would shed light on scattering are also rare—in particular, evidence that

records in question concern the tithe levied by the Cathedral of Cambrai in two northern French villages, Onnaing and Quarouble. Located only 4 kilometers outside the city of Valenciennes, the two villages were adjacent, their centers a mere 2 kilometers apart. The villages and their environs (part of the area known as the Hainault) had come to the classic three-field crop rotation rather late in the Middle Ages, but the three-field regime was certainly established by the sixteenth century, as were the hallmarks of open-field farming, including grazing on the stubble. The region was also one of scattered holdings, with typical plots measuring between roughly 0.1 and 1.0 hectares.⁸

The Cathedral possessed the right to an 8-percent tithe on certain parcels of land known as *taques* in Onnaing and Quarouble. There were 27 of the *taques*, covering 49 percent of the surface of Onnaing and 39 percent of Quarouble. Unlike most tithe owners, who leased their tithe rights out for a fixed cash rent over a number of years, the Cathedral of Cambrai insisted on collecting its tithe in kind one year at a time, and it did so separately for each *taque*. By the eighteenth century, the process of collection had settled down to a routine. On the eve of the harvest, the cathedral would auction off the right to collect the tithe on each *taque* to the highest bidder, with bids made not in money, but in grain—wheat if the standing crop on the *taque* was wheat, oats if it was oats. The highest bidder had the right to 8 percent of the crop on the *taque* after the grain farmers had harvested it; he owed the Cathedral either the amount of grain he had bid or a cash payment equal to the bid times the post harvest price of grain in nearby Valenciennes, where his payment was due.⁹

In the eighteenth century it was the cash that changed hands, although the Cathedral continued to insist on bids in kind.¹⁰ The bidders were by and large residents of Onnaing and Quarouble, presumably farm owners whose workers were already out in the fields

operating farms (as opposed to owned farm land) were actually scattered. Landownership was certainly scattered, but whether the operating farms were is not clear, because the rental market could have rearranged holdings considerably.

⁸Sivery [1977] (pp. 88-89, 98-106, 112, 132); Morineau [1971] (pp. 34, 98); Lefebvre [1959] (pp. 47, 90-91, 210-217); Demangeon [1905] (pp. 345-57). We do not want to suggest that the local agriculture was rigid and backwards. By the end of the eighteenth century, for example, local farmers had adopted a number of progressive techniques, such as the planting of clover, the preparation of seed with arsenic, the use of a wide variety of fertilizers, and intensive hand cultivation of small plots.

⁹Archives Départementales du Nord, 4 G 3456; Morineau [1971], pp. 32-35, 97-162. The cash payments were based on the November 30 price for wheat and the Christmas price for oats—the dates when the wheat and oats payments were due in Valenciennes. In addition to the tithe rights on the 27 *taques*, the Cathedral possessed similar rights on parcels known as the *espiliers*. Areas are not available for the *espiliers*, in contrast to the *taques*, but the *espiliers* appear to have been smaller bits of dispersed land, sometimes outside the usual crop rotation. In the eighteenth century the *espiliers* produced 25 to 30 percent of the total tithe income from both *taques* and *espiliers*: Morineau [1971], p. 98. We will use the *espiliers* for some but not all of our calculations below.

¹⁰The Cathedral considered switching to long-term cash leases at the end of the Old Regime, but the Revolution cut short the project: Morineau [1971], p. 100-102. It probably adhered to the in-kind bids, even though the tithe was actually paid in cash, because it wished to protect its tithe rights against legal attack. When in-kind seigneurial dues were let out on long term cash leases in the region of Onnaing and Quarouble, the lease sometimes paved the way for a legal argument that the rights to the dues themselves had lapsed; the Cathedral might have feared the same fate for its tithe rights if they were leased for cash. See Lefebvre [1959], p. 148-50. The eighteenth-century auctions stipulated that the

bringing their own harvested grain into local barns. For them the marginal cost of hauling in a little additional grain from the taques was low, all the more so since they probably bid on the taques where their own crop stood. With the marginal cost of bringing the tithe in near zero, it is reasonable to assume that the highest bidder would offer an amount equal to 8 percent of the quantity of grain standing on the taque. Such an argument assumes, of course, that competition among the bidders would drive their profits down to zero, but the bidders were numerous and no one seemed to monopolize the tithe collection. On July 26, 1707, for example, the cathedral auctioned off the right to the tithe on 7 taques planted in wheat and 11 planted in oats to a total of 21 high bidders – usually, a separate high bidder for each taque.¹¹

The winning bids thus furnish an estimate of 8 percent of the grain output on each taque. But what precisely were the taques? Averaging 41 hectares in size, they were too large to be individual strips of land. Rather, each taque was a group of adjacent strips, all sown with the same crops and in all likelihood ploughed in parallel—what was termed a furlong in England, or a *quartier* or *delle*, to cite but two of the common names in other parts of France. Indeed, on occasion the Cathedral even called the taques “quartiers.” Each taque therefore included the holdings of a number of individuals and each was planted with a single crop or left fallow in any given year. The crop would of course change with the three-field rotation, shifting from wheat to oats and then to fallow before beginning the cycle anew. In turn, each taque belonged to one of the three larger land units in each village that made up the three field system – units called great fields in England and known in Hainault as *royages*. Each *royage* included all the taques and other parcels that were sown with the same crop and moved through the crop rotation together.¹²

tithe be levied in kind and that bids be made in kind, but final payment had to be in cash: AD Nord, 4 G 3456.

¹¹AD Nord, 4 G 3456, July 26, 1707, and *passim*; because a few of the tithe rights were won by joint bidders, there were more high bidders than taques. Conceivably, one individual could have monopolized collection of the tithe on each taque, but a perusal of the eighteenth-century auction records suggests that was not the case. Unfortunately, the auction records do not list the number of individuals who bid for each taque, but Morineau argues that it was probably large because numerous individuals usually had holdings on each taque: Morineau [1971], p. 34, 102. For evidence that the high bidders were local farmers, see *ibid*, p. 102, and AD Nord, 4 G 3456, July 9, 1784, where all 11 of the high bidders for taques in Onnaing were from Onnaing, and all 9 in Quarouble were from Quarouble. Presumably bidders would have adjusted their bids slightly to reflect the difference between the farm gate price and the Valenciennes price for grain, but this adjustment can be safely ignored because Valenciennes was a mere 4 kilometers away. It also seems reasonable to ignore the risks involved in the collection process. They were minimal—the grain was ready for harvest and the bidders did not have to guess the future price of grain—and with a handful of risk neutral bidders the auction should have soon pushed very close to eight percent of the grain on the taque.

¹²For the size of the taques, see the corrected areas in Morineau [1982] 2:625-643. For the use of the word “quartiers” to describe the taques, see AD Nord, 4 G 3442, and for the peculiar meaning of the word *royage* in Hainault, see Godefroy, *Dictionnaire du français médiéval*, s.v. “royage”. One taque, known as Dessous-la-Crête, seemed to have two parts: 35 hectares in the first *royage* in Onnaing and 20 hectares in the second *royage* in Onnaing. Each part was counted for our purposes as a separate taque. All areas here concern only the taques and not the additional parcels known as *espiliers*, for which no areas are available.

Without a map, we cannot tell how close the taques were, nor whether the ones in a given royaume happened to be nearer than the others. Unfortunately, no suitable map depicts the taques, but whatever their location in Onnaing and Quarouble, they had to be closer than McCloskey's manorial farms. The distance between two taques located within one of the villages would be comparable to that between individual strips, and even if we took one taque in Onnaing and a second in Quarouble, the distance would be relatively small. The two villages, after all, were only 2 kilometers apart, whereas few of McCloskey's farms stood within 3 kilometers of one another. Indeed, the closest of his farms were 2.4 kilometers apart—further than Onnaing and Quarouble.¹³

Correlating the grain output of all the taques over a number of years provides us with an estimate for R . To be sure, such a calculation raises certain questions. In the first place, for some taques, the winning bidder had to pay a small, fixed amount of grain to the local priest; for such taques, the winning bid and hence the assumed grain output would be artificially reduced each year by the same small constant. Yet although the grain output would be a bit lower, the correlations between the grain output of different taques would not be affected, for subtracting a constant would leave the correlations unchanged.

A second problem is that the winning bids involve the bidder's estimate of the grain output, an estimate that was undoubtedly made with error. Unlike the subtraction of a constant, the error would affect the calculation of R . If the actual time series of grain outputs for taque i is y_i and the time series derived from the winning bids is x_i , then:

$$x_i = y_i + e_i \tag{1}$$

where e_i is the error resulting from the use of the winning bids. If the e_i are independent of the y_i and one another – a reasonable assumption – then:

$$\frac{\text{cov}(x_i, x_j)}{\sigma_{x_i} \sigma_{x_j}} = \frac{\text{cov}(y_i, y_j)}{((\sigma_{y_i}^2 + \sigma_{e_i}^2)(\sigma_{y_j}^2 + \sigma_{e_j}^2))^{\frac{1}{2}}} \leq \frac{\text{cov}(y_i, y_j)}{\sigma_{y_i} \sigma_{y_j}} \tag{2}$$

The value of R derived from the winning bids is the expression on the left of (2) averaged over all pairs of taques, while the true R is the average of the expression on the right of (2).

The bids therefore lead to an underestimate of R , though by only a small margin because the errors e_i are likely to be tiny. After all, the farmers who bid on the tithe knew

¹³McCloskey, [1989] pp. 40-43. So as to be consistent with McCloskey, the distance between Onnaing and Quarouble is measured here as the distance between their centers. Old-Regime maps of Onnaing and Quarouble, which one would expect to show the taques, concern only meadows, woods, and adjoining land, not the whole villages: AD Nord, 4 G 3454, 3510, 3520. The Cathedral's eighteenth-century *terrier* did list the taques, but unlike some *terriers* of the period, it lacked maps: AD Nord, 4 G 3442. Tax records are of no help either: right through the Revolution they too lacked maps. One could consult the nineteenth-century cadastre—it was unfortunately not available to researchers during our stay at the AD Nord—but that would be of little help, for even if holdings had not been consolidated, the taques would have disappeared and all one could do would be to reason by analogy with *quartier* names. Cf. Lefebvre [1959], pp. xvii-xxi, for what one can expect of the documents in the region.

well how to estimate the amount of grain standing in a field. They made such estimates frequently, not only when they bid on the tithe but when they evaluated relatives' estates or testified in court. The errors they made – the e_i – would be minor. We can reduce the magnitude of the errors even further if we restrict ourselves—as we shall—to the tithe records of the eighteenth century, when the delay between the tithe auction and the actual harvest was at most a matter of days. In earlier centuries, the tithe rights were sold off in May or June, but in the eighteenth century the auctions took place in July, the month when harvesting began. In 1707, for instance, the tithe was auctioned off on July 26, perhaps moments before the onset of the harvest.¹⁴

Under such conditions the errors e_i were in all likelihood minuscule. Suppose, for example, that they were normally distributed with mean zero and standard deviation equal to 10 percent of the average yield on a taque. Under these assumptions, the winning bidders would be within 20 percent of the true yield roughly 95 percent of the time—hardly unreasonable accuracy for experienced bidders competing against one another only a day or two, or perhaps even hours, before the harvest. Equation (2) then implies that we underestimate R by only 15 percent.¹⁵

McCloskey's R concerns a single crop, and we shall limit ourselves to calculating it for wheat.¹⁶ The calculation entails correlating wheat yields from the eighteenth century for each pair of taques that grew wheat simultaneously and then averaging the correlations over all the pairs. The correlations also permit a test of another of McCloskey's ideas, for if he is correct, then the correlations should decline with the distance between taques. The precise distance between each pair of taques remains unknown, but we can at least distinguish those pairs with both taques in the same village, which would have been closer on average than the pairs spanning both Onnaing and Quarouble. Presumably, their correlations would be higher too.

What then do the correlations reveal? When both taques lay in the same village, R was a low 0.473 (Table 1). For the pairs spanning the two villages, it was lower still—0.386—just as McCloskey's relationship between yield correlations and distance would suggest. Nor does the smaller R for taques in different villages appear to be a statistical fluke—or

¹⁴Morineau [1971], pp. 100-104; AD Nord, 4 G 3456. A second reason for restricting the analysis to the years 1701-1790 is that before the eighteenth century the tithe rights were sometimes sold for several years at a time and the payments subsequently reduced in case of disaster. One additional cause for worry—as it turns out, a groundless one—is the accuracy of Morineau's publication of the original figures from Onnaing and Quarouble. Morineau's calculations with the data have been attacked as inaccurate, and one might therefore worry about the accuracy of his publication, which we relied upon for our calculations. While his arithmetic may have contained errors, a comparison with the original manuscript sources suggests that the raw published data itself was transcribed with reasonable accuracy. We have, however, converted what appear to be the decimal tenths in his tables to the eights they actually are.

¹⁵This calculation uses the coefficient of variation of the winning bids – in other words, the standard deviation of x_i in equation (1) divided by its mean. When estimated by averaging over all the taques and espilliers, the coefficient of variation turns out to be 0.275. The calculation here concerns eighteenth-century wheat yields only.

¹⁶McCloskey does consider correlations between different crops, but it is the single crop R that is “critical.”: [1976], 132-36, 145.

at least that is what is suggested by a regression of the correlations on a constant and a dummy variable for taques lying in the same village.¹⁷ Since Onnaing and Quarouble are only 2 kilometers apart, the lower R for taques spanning the two villages is probably the figure relevant to open field agriculture. The pairs of taques that lay within the same village and grew wheat at the same time were necessarily in the same royage and thus perhaps closer than individual strips needed to be, particularly if the royage was compact. The pairs that spanned the two villages, by contrast, were probably no further apart than typical peasant holdings.

With such a low R , even large errors in the bidders' estimates of the yields would be unlikely to raise R to unsettling levels. If the bidders' errors had a standard deviation of 15 percent of the crop—incredible sloppiness, given the circumstances—then the true R would be 0.548, or 0.672 if we were to utilize the higher, though somewhat less reasonable, estimate based on taques in the same village. If they erred with a standard deviation of 10 percent—and they probably achieved greater accuracy than that—then the true R would be 0.444 or 0.544, depending on which estimate of R we used.¹⁸ All of the figures are obviously low, most even lying below McCloskey's own estimates. His argument, apparently, is vindicated on all counts, but before judging the debate closed, we should analyze the evidence in a different way, for as we shall see, the simple output correlations for a single crop conceal far more than they reveal.

3 A Portfolio Analysis

Several questions remain unanswered. First, how do we judge whether R is low enough? Equivalently, how do we gauge the effectiveness of the insurance that scattering provides? McCloskey did so in a relatively simple way, by measuring how much scattering reduced the likelihood of disaster, which he defined as a crop equal to half the normal.¹⁹ But the likelihood of disaster is not the only yardstick for evaluating insurance. It might suit a world of self sufficient farmers, but such a world, if it ever existed, was long gone from Western European agriculture by the early modern period. By the eighteenth century, for example, most peasants in the Hainault—the region of Onnaing and Quarouble—worked as agricultural laborers. Perhaps only 1 or 2 percent of them were independent.²⁰ The independent ones were by and large engaged in commercial agriculture, and they might well prosper when the harvest fell to half the normal, because of the inelastic demand

¹⁷If r is the yield correlation calculated from the winning bids for a pair of taques and z is a dummy variable that is 1 when both taques lie in the same village, then $r = .386 + .087z$ ($n = 224$, $R^2 = .03$) and the t -statistic of z 's coefficient is 2.69. The t -statistic assumes, of course, that the pairs of taques within a single village and the pairs spanning two villages have observed yield correlations that are normally distributed with the same variance but different means. All yield correlations here use data both from the taques and from the parcels known as espiliers.

¹⁸Because yields rose in the eighteenth century, the output series were non stationary. As a result, the correlations here may actually overstate the relationship between output on different taques. For further discussion, see below.

¹⁹McCloskey [1976], pp. 131-32, 143.

²⁰Lefebvre [1959], pp. 37, 289.

for grain. Only the farm laborers would suffer, but they had little or no land to scatter anyway.

The evidence from other parts of Europe is similar. Self sufficiency, even in the late Middle Ages, was surprisingly rare; many peasants hired labor and marketed their crops. Furthermore, even self sufficient peasants might have defined disaster differently or reacted to it in different ways.²¹

What we need, therefore, is a more supple yardstick, one that takes into account the costs and profits of farming and allows for differences in wealth and in aversion to risk. One obvious technique is to rely upon portfolio analysis from the field of finance. The early modern landholder's problem could be rephrased as that of choosing an optimal portfolio of land holdings based on the expected financial returns from farming and their variances. Of course such a portfolio analysis entails certain theoretical assumptions—none more drastic though than McCloskey's focus on averting disaster—and to a historian it may seem anachronistic when applied to the world of early modern landholders.²² But it is, after all, merely a model, a way of thinking about the problem—our way of thinking, rather than theirs—which can nevertheless shed light on the difficulties they faced. While it might not be reality as perceived by the landholders, it could well reveal the advantages that they discerned in scattering their holdings. And as we shall see, it has the great advantage of permitting comparison with other available forms of insurance.

The portfolio analysis requires time series of financial returns for each parcel or field where the landholder might own land – for example, each taque. The output of each parcel is not enough, for we need to know what the financial return to farming each parcel is, returns after the crops are sold and the labor paid. If we only examine output fluctuations, as McCloskey does, then we merely take into account the risks affecting physical output, but we ignore the changes in wages and prices, which, given inelastic demand, might have compensated the landholder for a drop in output. If we calculate returns, the price changes are obviously taken into account.²³

The portfolio analysis also resolves a more vexing problem with the output series. The problem is that average grain yields changed over time in Onnaing and Quarouble; in particular, they rose in the eighteenth century. It is therefore difficult to derive reliable estimates of R from the output series, because the output correlations confound the short term fluctuations of output that interest us with the long term change in yields. In technical terms, the output series are not stationary and they give inconsistent estimates

²¹For a discussion, see Newberry and Stiglitz [1981].

²²If McCloskey's way of thinking seems preferable, one could instead construct a frontier that marks the tradeoff between the expected return and the probability of disaster; the results would be the same. For the theoretical assumptions involved in mean variance analysis and other ways of analyzing risk, particularly in primitive economies, see Newberry and Stiglitz [1981]. Despite their warnings about the dangers of mean-variance analysis, they end up using it because it provides a good approximation. Using the approximation is certainly justified for our returns sample, because the single period returns are drawn from nearly normal distributions.

²³McCloskey is certainly aware of the dangers of ignoring price fluctuations. In his sample, price fluctuations can be safely neglected, since they are small relative to the output fluctuations.

of R . McCloskey avoids such difficulties by restricting his attention to short output series that run for only a few years, but such short output series, though they may be close to stationary, rob his estimates of precision.²⁴ Fortunately, our series of financial returns involve no such complications. They are stationary, even though the output series and the price series themselves are not. We can therefore employ the full 90 years of financial returns from the eighteenth century in order to sharpen the accuracy of our calculations.

The returns circumvent another serious obstacle as well. If we restrict the calculation of R to a single crop such as wheat, then we overlook the effects of the crop rotation. But once the other crops are included, R is much higher. Suppose, for example, that we correlate the output for entire royauges rather than for taques. For wheat alone (on the royauges growing wheat simultaneously), the correlations average 0.714; for oats, they average 0.757. But if we correlate not just wheat or oats but the entire output for the royauges on the same crop rotation, then the average correlation jumps to over 0.95.

It is the alternation of crops and fallow that is responsible for the increase. Because each crop has a different average yield, the output correlation is pushed upward by the regular variation in average yields. It is boosted even higher by the fallow every third year. One could limit one's attention to a single crop and thereby ignore the crop rotation's effect on output, but that would be tantamount to underestimating R and overestimating the value of scattering.²⁵ With the financial return series, by contrast, no such difficulties arise. Unlike the output series, the returns take into account wheat, oats, and fallow as well, for they measure each year's financial contribution, whatever the crop. That is a powerful argument in their favor.

To use the returns, we recast the landholder's dilemma as a portfolio problem, imagining that the landlord cares only about high mean returns and low return variances. He will then arrange his holdings so that, at any given level of return for his entire land portfolio, his return variance will be minimized. In mathematical terms, the landowner faces the following minimization problem:

$$\min \omega' \Sigma \omega \tag{3}$$

subject to

$$1' \omega = 1 \tag{4}$$

$$z' \omega = \mu \tag{5}$$

and

$$\omega_i \geq 0 \quad \forall i \tag{6}$$

²⁴McCloskey argues that correlating short output series fits the peasants' own expectations, but the peasants of course were not correlating any series, short or long. They evaluated scattering not by calculating correlations but by looking to their experience, experience that may have passed from father to son and stretched over generations. Our task is quite different: to determine whether scattering had any benefits by measuring parameters such as R as accurately as possible. The accuracy is easier to achieve with long output series.

²⁵McCloskey's solution to the problem is to use correlations of different crops such as wheat and oats, but in doing so, he overlooks the alternation of fallow.

for each component ω_i of ω . Here ω is a vector of portfolio weights telling what fraction of his property lies in each parcel where he can own land, Σ is the variance-covariance matrix of financial returns for all the parcels, z is the vector of expected returns for the parcels, and μ is the expected return of his entire portfolio. Constraint (4) simply means that the weights sum to 1, while (6) says that the weights must be non-negative—in the language of finance, the landowner cannot sell short his assets. Given a return μ on his portfolio, equation (5) implies that the landowner chooses weights ω to minimize the return variance (3). He does so, it is worth stressing, whatever his own tastes and attitude toward risk. There are of course a number of solutions to the minimization problem. The solutions trace out a surface known as the mean-variance efficient frontier, and given the landlord's own level of risk aversion, he simply chooses the μ and the ω on the mean-variance efficient frontier that maximize his own expected utility.²⁶ Our formulation of the landowner's problem thus allows for great differences in tastes and in attitudes toward risk.

Ideally, we would like to solve problem (3) for each taque and allow the landowner to spread his land out over all 27 taques. Working with all 27 taques, though, obscures the results without changing any of the conclusions. We shall therefore restrict ourselves to a choice among smaller groups of taques and among the six royaiges in Onnaing and Quarouble. Despite the restriction, we can still determine whether the optimal portfolios—those along the mean-variance efficient frontier—are scattered and whether scattering really does contribute to reducing the portfolio variance.²⁷

The first step in the portfolio analysis is to convert the grain yield figures into series of returns for each taque, or for each royaige if we are solving the portfolio problem for the royaiges. Ideally, the returns should incorporate the total revenue and the total costs incurred on a given taque or royaige, with revenues and costs based on the market prices of grain, land, labor, and capital. Unfortunately, despite efforts to find better data, some of our price series are far from perfect. Our series of returns are thus only approximations—albeit reasonable ones—to the actual returns.

To calculate total revenue, we multiplied the wheat and oats output of each taque or royaige by the price of wheat and oats in the city of Montdidier. Montdidier lay 100 kilometers from Onnaing and Quarouble, but it proved impossible to find useable price series for closer markets. Prices proved unreliable in Valenciennes, which was only 4 kilometers from Onnaing and Quarouble, and the same was true in other nearby markets, such as Douai and Lille. In the end, Montdidier was the closest market whose prices could be trusted; although the distance from Montdidier to Onnaing and Quarouble was not small, the Montdidier price and that in Onnaing and Quarouble appear to have been closely correlated.²⁸

²⁶For a discussion of portfolio analysis, see Markowitz [1987]. In our case, the portfolio weights are non-negative, and riskless borrowing and lending are not possible. Under these conditions, the mean-variance frontier is a set of parabolic sections with kinks at the joints. The number of kinks equals the number of portfolio weights that equal zero. See Dybvig [1984] for details.

²⁷Calculations for all 27 taques are available from the authors; they do not change the results.

²⁸The Valenciennes prices would seem the obvious ones to use for the two villages, because Valenciennes

To calculate total costs, we began with estimated labor inputs derived by George Grantham. The numbers we used were those Grantham gives for the region that included Onnaing and Quarouble – the French department of the Nord (Table 2).²⁹ The next step was to combine Grantham’s labor inputs with an appropriate local wage series in order to compute total labor costs, but finding such a series proved difficult. The regional archives (the departmental archives of the Nord) did not seem to have a suitable source for eighteenth-century unskilled wages—wages paid in cash with tasks specified—and no appropriate published series exists for the region. We were therefore forced to rely on the wages of unskilled laborers in Paris. As could be expected, Parisian wages were higher than those in the countryside near Onnaing and Quarouble: eighteenth-century evidence suggested that Onnaing and Quarouble wages ran only 65 percent of what they did in Paris. We therefore set our wage series equal to 65 percent of the Parisian series; variations in this figure led to similar results.³⁰

was practically next door. Some seventeenth-century prices from Valenciennes are published in Morineau [1971], p. 103, but the published series stops before our own period, the eighteenth century. While additional prices for the eighteenth-century may well exist in the manuscript Morineau used, the prices from Valenciennes leave much to be desired. In the first place, the units for oats are not entirely clear (on this, see Sivery [1977], pp. 64-65), and, worse yet, the prices seem suspiciously repetitive, particularly after 1650. Prices series from other nearby markets suffered from even more serious problems. In Douai and Lille—the two other obvious markets—intractable problems with units and monetary conversions rendered available price series useless. That left Montdidier as the closest market with reliable prices—slightly closer than Charleville and much closer than Abbeville. The Montdidier prices did correlate highly with the available Valenciennes prices ($r = 0.70$ for wheat, 0.50 for oats, 0.69 for wheat when differenced, 0.36 for oats when differenced), and their movement seemed particularly close before 1650, when the Valenciennes prices seemed more reliable. The Montdidier prices are taken from de Beauville [1875] 2:501.

²⁹Grantham [1991], pp. 8-10. We use Grantham’s estimates for stiff soils circa 1750. Grantham’s figure for threshing combines an estimate of the time required for threshing a hectoliter of grain and a figure for average yields. He reports that threshing operations consumed one man day per hectoliter of output and that average yields in the Nord were seventeen hectoliters per hectare. Since we already have yield estimates, we multiply our yields by Grantham’s man days per hectoliter estimate in calculating our costs for threshing.

Labor inputs for oats were not exactly the same as for wheat, which benefitted from more manure and more plowing. Grantham attributed fallow plowing and manuring operations (both of which came after the oats but before the wheat) to wheat production. In constructing our returns, we treated oats in two different ways. The first assumes the same amount of plowing for oats as for wheat and the second places plowing used in oat production at half of Grantham’s wheat plowing input figure. In both cases, all manuring operations were attributed to wheat and none to oats. The results presented here will be for the returns figures computed assuming the same plowing for oat production, although our conclusions hold up regardless of which oat return measure is employed. Harvesting costs were assumed to be the same for both crops, for in contrast to most parts of France, the scythe was used for both wheat and oats in the Nord in the eighteenth century. Threshing oats took slightly less time but the differences were small enough to ignore. For details, see Meuvret [1977-88], 1 (*Texte*): 166-69, 1 (*Notes*): 175, note 11; Tessier [1787-1821] s.v. “Battage”.

³⁰Guignet [1977] (p. 566) contains wages for female lace makers in Valenciennes, but we need the wages of unskilled males. Furthermore, his series only covers the years 1748-1774. The evidence that local wages were 65 percent of those in Paris comes from a variety of sources. Young [1931] reported that wages were 0.6 livre/day in Picardie, which lay between Paris and the Hainault. Paris wages at the time were near 1.25 livre/day, suggesting that countryside wages were only fifty percent of Paris wages. Deyon [1967] noted that workers in the city of Amiens, also between Paris and the Hainault, received 0.6 livre/day in 1700-20. Paris wages during this period were hovering just below 1 livre/day. In the 1720s

Capital costs posed similar problems because there was no local price series for the major component of agricultural capital – livestock. The only recourse was to use accounting information from the Paris Basin, where agricultural technology was similar. There the rental cost of capital did not vary greatly in the eighteenth century, and the accounting information suggests that it absorbed about 22 percent of total costs. Our capital costs we assumed to be the same.³¹

To figure the cost of land required a local land rental series, but such a series proved impossible to find. The local ecclesiastical archives—typically the best source for rental data— contained only isolated leases for Onnaing and Quarouble and lacked anything like a rental series for the two villages. Tax records shed no light on the rental rate of land either; worse yet, much of the regional lease information was contaminated by the custom known as *mauvais gré*, which restricted rent increases and kept the rental rates stated in leases below the market price of land. The only alternative was to rely upon a decennial rent series from 34 villages in the vicinity of the city of Amiens. On average, these villages lay slightly over 100 kilometers from Onnaing and Quarouble, and their rent levels were lower than in Onnaing and Quarouble. In fact, the few useable leases we did find from Onnaing and Quarouble implied that rent in the 34 villages was lower by a factor of approximately 2.5. We therefore multiplied the time series from the 34 villages by 2.5 to give us an overall rental trend and corrected for differences in land quality among taques in Onnaing and Quarouble via differences in average yields. Changing the 2.5 scale factor did not disturb our results.³²

Given total revenues and total costs, it is easy to calculate a rate of return. For a farmer renting a portion of a given taque or royage, it is:

$$\text{return} = \frac{\text{total revenue} - \text{total costs}}{\text{land rent} + \text{total costs}} \quad (7)$$

The return is the same, it should be noted, whether the farmer rents the whole taque or merely a portion of it. More important for our purposes, though, is the rate of return for

Deyon estimated wages in Amiens to be 0.8 livre/day while Paris wages were somewhat over 1 livre/day. Deyon suggests that wages in the countryside around Amiens were lower than these estimates. Lefebvre [1959] estimated wages for unskilled laborers in the Nord during the 1780s at about 0.625 livre/day if one takes into account board usually granted to agricultural laborers in this area. Given these estimates, 65 percent of Paris wages seemed a not inappropriate estimate for Onnaing and Quarouble. In any event, our conclusions are not sensitive to the 65 percent scale factor. We tried scale factors ranging from 55 to 75 percent; our results were not greatly changed.

³¹The capital share here is net of seed; it did not vary greatly in the eighteenth century. See Hoffman [1991b] and Hoffman [1991a] (pp. 27-32).

³²For *mauvais gré* and the rental market, see Lefebvre [1959] and Hoffman [1991]. The correlation matrix of returns (the key to our analysis) is largely unaffected by our choice of the 2.5 rental scale factor. Indeed, multiplying the Amien rent series by anywhere from one to three changes none of our conclusions. To adjust for land quality differences within the villages, we computed the average output on each taque or royage over the ninety years for which we had tithe data. We then divided each of these average output figures by Grantham's estimate of average output for the department of the Nord in 1750 (17 hectoliters per hectare). For each taque or royage, this provided an individual scale factor which was multiplied by the rental time series constructed for Onnaing and Quarouble.

a landowner who farms his own property. To calculate it, we assumed that land rented for 4 percent of its sale price, as was common in the eighteenth century, and simply multiplied our rental figures by 25 to get a sales price series. The owner's rate of return is then:

$$\text{return} = \frac{\text{total revenue} - \text{total costs}}{\text{land price} + \text{total costs}} \quad (8)$$

We omitted changes in the price of land from (8) because they proved to be negligible. The resulting average financial returns are listed by royaume in Table 3.

The returns, of course, are approximations, and one might rightly worry about their accuracy. A simple way to check them is to calculate the ratio of profits to land rents:

$$\frac{\text{total revenue} - \text{total costs}}{\text{land rent}} \quad (9)$$

If the revenues and costs are accurate, then the returns will be accurate too. But the difference between revenues and costs will be profits. With a competitive rental market for land, the profits will be siphoned off by landlords, leaving the ratio (9) close to one. If the ratio is indeed close to one, it will lend credence to the returns. Ratios for each royaume appear in Table 4.

Although the ratio exceeds one on each royaume, it does so by only a small margin. The excess might reflect slight errors in the prices or land values or – more likely still – entrepreneurial profits, which would prevent all the earnings from flowing to the landlord. In addition, the land market might not have been perfectly competitive because of *mauvais gré*; if so, the ratio would remain well above one.³³ In any event, the ratio is close enough to one to support confidence in the financial returns. Also supportive of the returns is their level. For owners they in fact hover close to the rate prevailing on long term loans – further evidence in their favor.

Once calculated for each taque and royaume, the returns make clear the benefits of holding separate plots of land. A landowner, for example, could cut his risks drastically merely by spreading his holdings among the six royaumes. To see why it suffices to solve the portfolio problem (3) for the royaumes.

For various portfolio returns μ , we can calculate the portfolio weights that minimize the landlord's portfolio variance and thereby trace out points along the mean-variance efficient frontier; a number of such points are listed in Table 5 and depicted in Figure 1. From the frontier, it is obvious that farming different royaumes greatly reduced the

³³We compute returns not only for royaumes, but also for the individual taques that comprise royaume 3 (in Onnaing) and royaume 6 (in Quarouble). The average of the ratio test is 1.19 for the taques in royaume 3 and 1.28 for those in royaume 6.

portfolio variance. To achieve an expected return of 0.055, for example, a landowner could consolidate all his holdings in royage one in Onnaing; his portfolio would then have a variance of .004297. Were he instead to adopt a mean–variance efficient portfolio, he would spread his holdings according to the weights shown in Table 6, opposite the expected return of 0.055. He would then own land in royages one, three, four, five, and six, and his portfolio variance would fall to .000753. Compared to the portfolio consolidated in royage one, the variance would have dropped 82.5 percent.

At first glance, the dramatically lower variance might appear to support McCloskey's argument about scattering, but a closer look at the evidence suggests otherwise. What we have to examine are the correlations between the financial returns of the various royages. When the correlations are low or negative, the landowner can indeed cut his portfolio variance by scattering his holdings. But when they are highly correlated, scattering does little to spread his risk.

For the royages, the returns correlations are either over 0.97 – and hence far too high – or else negative (Table 6). If scattering really did reduce risks, then why would some of the correlations be nearly one? Such high correlations might be understandable for royages within the same village, where the effects of scattering would be muted, but the pairs of royages with high correlations (royages one and four, royages two and five, and royages three and six) all lay in different villages. In separate villages, where the effects of scattering would presumably be most pronounced, the correlations should be low or negative, but certainly not above 0.97.

To be sure, there are other royages with negative correlations. But what distinguished them was not scattering but the crops they grew. In every case, if a pair of royages had a negative correlation, then the royages grew different crops. In Onnaing, for example, royages one and two were never sown with the same crops: they marched through the crop rotation one year apart. Their return correlation was -0.242. Like royages one and two, many of the royages with negative correlation lay in the same village. The same was true of royages four, five, and six in Quarouble. If McCloskey's argument about scattering were correct, the correlations would not dip so low for royages within a single village.

Apparently, what did reduce risk was not scattering but the crop diversification inherent in the three-field system. The royages with low correlations never grew the same crops. Those with high correlations (royages one and four, two and five, and three and six) always did (Table 6). Whether the royages were in different villages mattered little – contrary to what McCloskey's argument would lead us to expect. After all, if he were correct, the correlations should have been consistently high for royages in the same village and consistently low for royages in different villages.³⁴ It is clear that a landowner did

³⁴McCloskey does not deny the importance of growing different crops, and he might rightly argue that both scattering and crop diversification reduced risk. The issue then is whether scattering provided much additional insurance. If it did, then we could detect the effect of scattering by looking at the returns correlations between royages growing different crops. These correlations should be much lower when the royages are in different villages and the effect of scattering is more pronounced. For our royages, though,

not have to scatter his fields wildly to reduce his risk; rather, he simply had to farm land in each of the three parts of the crop rotation. The crop rotation gave him the necessary crop diversification, and he did not have to sow dozens of additional crops.

Here McCloskey might counter that scattering across royaes is not a fair test. The royaes, he might say, were too large and heterogeneous. Encompassing a wide variety of soils, they would already have exhausted the benefits of scattering. If so, then little would be gained by holding land in different royaes, beyond the benefits of crop diversification. Our results, he might conclude, would come as no surprise.

Yet it is not so easy to dismiss the evidence from the royaes. If they seem too large – keep in mind that they are hardly larger than the manorial farms McCloskey himself uses – then the analysis can be repeated for the taques, which are certainly small enough to reveal the benefits of scattering. And if scattering mattered, independently of crop diversification, then its benefits should stand out even on taques sown with the same crops. In other words, a landowner should be able to reduce his portfolio's variance by spreading his holdings across different taques, and he should be able to do so even if the taques grew identical crops.

Was this possible on the taques? Consider, for example, the taques in royae three in Onnaing. They all grew the same crops, year in and year out. If the royaes were indeed large and heterogeneous, then the six taques in royae three must have offered considerable opportunity for diversification by scattering alone. The returns correlations suggest, however, that these taques provided little in the way of insurance. Although their returns correlations are not as close to one as some from the royaes, they are still quite high: they range from 0.743 to 0.960 (Table 7). None are negative. And the correlations are just as large for the other taques that grow the same crops – for instance, those in royae six in Quarouble.

There is another way to appreciate how meager were the benefits to scattering across the taques in royae three: solving the portfolio problem. If we solve it for a landowner who can divide his holdings among these taques, we quickly see how little insurance scattering brings in the absence of crop diversification (Table 8). The solution with the lowest possible variance – one that might appeal to an ultra cautious landowner – had an expected return of 0.412 and a variance of .002467. It was scattered, but one could do almost as well without any scattering at all, simply by holding land in a single taque, taque five, which returned .0404 and had a variance of .00253. Similarly a landowner could concentrate his land in taque three and achieve a return of .0507 and a variance of .004194. To get a similar return (.0505) along the mean variance frontier, he would have to scatter his holdings over three taques, yet his portfolio variance would diminish only slightly to .003943. Gone were the gigantic reductions in variance that a landowner could enjoy by holding different royaes and diversifying his crops!

they are hardly lower at all: they average -0.230 for royaes in the same village and -0.233 for different villages, which suggests that scattering's contribution was minimal. Output correlations for taques lead to the same conclusion.

One might argue that limiting the landowner to the taques in royage three is too restrictive. Why not let him range over the eleven taques in royages three and six? Although they all grew the same crops, they spread over two villages and so offered ample opportunity for scattering to work its supposed magic. Yet adding the five extra taques from royage six did little to reduce the portfolio variance (Figure 2). Usually it declined by only 5 or 6 percent with the addition of the extra taques, even though they allowed the landowner to hold land in Quarouble instead of just Onnaing.³⁵

Not that scattering was completely ineffective. If we consider the portfolios made up of land from the taques in royage three, we see that many along the mean-variance efficient frontier involved some scattering (Table 8). Furthermore, holding a scattered portfolio was clearly superior to concentrating one's land in a plot such as taque four.³⁶ But by and large, scattering did little to reduce the portfolio's variance, and as insurance it paled to insignificance besides crop diversification. After all, a landowner could protect himself simply by rotating his crops; he did not have to scatter his fields.

If scattering provided so little insurance, why did it persist? The answer may lie with Fenoaltea's ideas, revised to take into account the imperfections of the pre-industrial labor market. Or it may lie with the workings of the land market, as Bruce Campbell has proposed.³⁷ But for the moment scattering remains what it has long been, a matter of mystery.

³⁵The royage six taques did contribute somewhat more at higher rates of return. With only taques from royage three, for example, the highest achievable expected return was .0534 with a .006073 variance. With the addition of taques from royage six, the optimal portfolio of assets with nearly the same return (.0535) included land in taques three, six, seven, and nine; its variance was .04738, some 22 percent below that of the portfolio restricted to the taques from royage three.

³⁶In equilibrium, the price of taque four would presumably decline enough so that it too would be held. Our imputed rent on taque four is probably too high and the return too low – a sign that we undoubtedly erred slightly in correcting for rent differences among the taques. Such errors, though, should not disturb our results, because the returns correlations matrix would remain nearly the same.

³⁷Campbell [1980]. He attributes scattering at least in part to the workings of the land market, but he fails to explain why buyers did not prefer consolidated holdings. If they did, then the land market should have led to concentration, unless it was obstructed by some intriguing imperfection.

Table 1. Wheat Yield Correlations 1701-1790		
	Pairs of taques within one village	Pairs with one taque in Onnaing and one in Quarouble
Average correlation	0.473	0.386
Number of pairs	106	118
Standard deviation	0.249	0.234
Source: Morineau [1971]		

Note: The wheat yield correlations are averaged over all pairs of taques growing wheat simultaneously including the espiliers. Both here and in all subsequent calculations, data from 1740 were eliminated because the 1740 tithe was commuted to a monetary payment.

Table 2. Labor Inputs	
	mandays per hectare
pre-harvest	14.65
manuring	8.1
harvest	9.3
threshing	17.0
Source: George Grantham, 1991.	

Note: In Grantham's calculations, wheat farming requires labor for four tasks: pre-harvest operations, manuring, harvesting, and threshing. Pre-harvest operations cover plowing, harrowing, sowing, and weeding. Manuring includes loading manure, transporting it to fields and then spreading it. Harvesting comprises cutting, binding, stooking, and transporting output from fields.

The figure for threshing is actually a combination of two of Grantham's other estimates. He argues that threshing required 1 manday of labor per hectolitre. He gives the average yield on fields in the department of the Nord as 17 hectolitres per hectare. Multiplying these two numbers yields an estimate of the average labor input per hectare associated with threshing in the Nord. For our returns, we computed the labor inputs associated with threshing by multiplying the output on each of our fields (measured in hectolitres per hectare) by Grantham's estimate of 1 manday of labor per hectolitre threshed.

Table 3. Average Return on each Royage 1701-1790

Owner's Return			
	Return	St. Dev.	Variance
royage1	.0550	.06555	.004297
royage2	.0564	.06741	.004544
royage3	.0488	.06455	.004167
royage4	.0572	.06551	.004292
royage5	.0585	.06478	.004197
royage6	.0533	.07160	.005126
Renter's Return			
	Return	St. Dev.	Variance
royage1	.1893	.559460	.312995
royage2	.1998	.549291	.301720
royage3	.1439	.507234	.257286
royage4	.2351	.590245	.348389
royage5	.2531	.566378	.320784
royage6	.2049	.609967	.372059

Source: See Text

Note: Royages one, two, and three were in the village of Onnaing; four, five, and six were in Quarouble.

Table 4. Ratio of profits to rental value of land	
royage1	1.329
royage2	1.360
royage3	1.212
royage4	1.391
royage5	1.413
royage6	1.322
weighted avg	1.328
Source: See text	

Note: For locations of the royages see table 3.

Table 5: Mean-Variance Efficient Portfolios, Royages

Exp. mean	variance	Portfolio Weights by Royage					
		1	2	3	4	5	6
.0543	.000738	.233	.078	.326	.110	.254	.000
.0546	.000740	.185	.000	.314	.163	.338	.000
.0550	.000753	.103	.000	.274	.249	.347	.027
.0554	.000769	.092	.000	.201	.262	.352	.093
.0558	.000788	.080	.000	.125	.275	.358	.161
.0562	.000810	.069	.000	.049	.288	.363	.230
.0564	.000820	.064	.000	.019	.294	.365	.258
.0566	.000836	.002	.000	.000	.357	.369	.272
.0570	.000927	.000	.000	.000	.378	.430	.192
.0572	.000994	.000	.000	.000	.386	.453	.161
.0574	.001141	.000	.000	.000	.398	.492	.110
.0578	.001477	.000	.000	.000	.418	.553	.028
.0582	.002301	.000	.000	.000	.234	.766	.000
.0585	.004196	.000	.000	.000	.000	1.00	.000

Source: See text

Note: For the locations of the royages see table 3. Exp mean is the expected portfolio return μ ; the variance is the total portfolio variance $\omega'\Sigma\omega$; and the weights give the portion of land ω_i held in each royage.

Table 6: Returns Correlation Matrix

Royages	1	2	3	4	5	6
royage1	1.00					
royage2	-.242	1.00				
royage3	-.231	-.243	1.00			
royage4	.970	-.211	-.254	1.00		
royage5	-.295	.973	-.180	-.260	1.00	
royage6	-.202	-.255	.978	-.215	-.191	1.00

Source: See text

Note: Royages 1,2, and 3 were in Onnaing; 4,5, and 6 in Quarouble. Royages 1 and 4 grew the same crop. So did 2 and 5, and 3 and 6.

Table 7: Returns Correlation Matrix

Tagues in Royage 3, Onnaing						
	1	2	3	4	5	6
taque 1	1.00					
taque 2	.925	1.00				
taque 3	.877	.960	1.00			
taque 4	.920	.797	.743	1.00		
taque 5	.816	.799	.811	.746	1.00	
taque 6	.868	.890	.873	.749	.866	1.00

Source: See text

Note: All taques in royage 3 grew the same crops.

Table 8: Mean-Variance Efficient Portfolios
 Taques in Royage 3.

Royage 3		Portfolio Weights by Taque					
Exp. mean	variance	1	2	3	4	5	6
.0412	.002467	.000	.232	.000	.000	.768	.000
.0415	.002472	.000	.297	.000	.000	.703	.000
.0425	.002530	.000	.255	.000	.000	.588	.157
.0435	.002614	.000	.211	.000	.000	.475	.315
.0445	.002724	.000	.131	.056	.000	.403	.411
.0455	.002845	.000	.026	.151	.000	.358	.464
.0465	.002980	.000	.000	.216	.000	.262	.522
.0475	.003138	.000	.000	.272	.000	.149	.580
.0485	.003312	.000	.000	.327	.000	.035	.637
.0495	.003565	.023	.000	.530	.000	.000	.446
.0505	.003943	.171	.000	.584	.000	.000	.245
.0515	.004415	.318	.000	.638	.000	.000	.044
.0525	.005072	.640	.000	.360	.000	.000	.000
.0534	.006073	1.00	.000	.000	.000	.000	.000

Source: See text

Note: The mean returns, and the portfolio variances have the same meaning as in table 5, but the portfolio now consists of land in the taques of royage 3. The portfolio weights ω_i therefore give the portion of land held in each taque.

Figure 1. Mean-Variance Frontier
Portfolios from all Royages

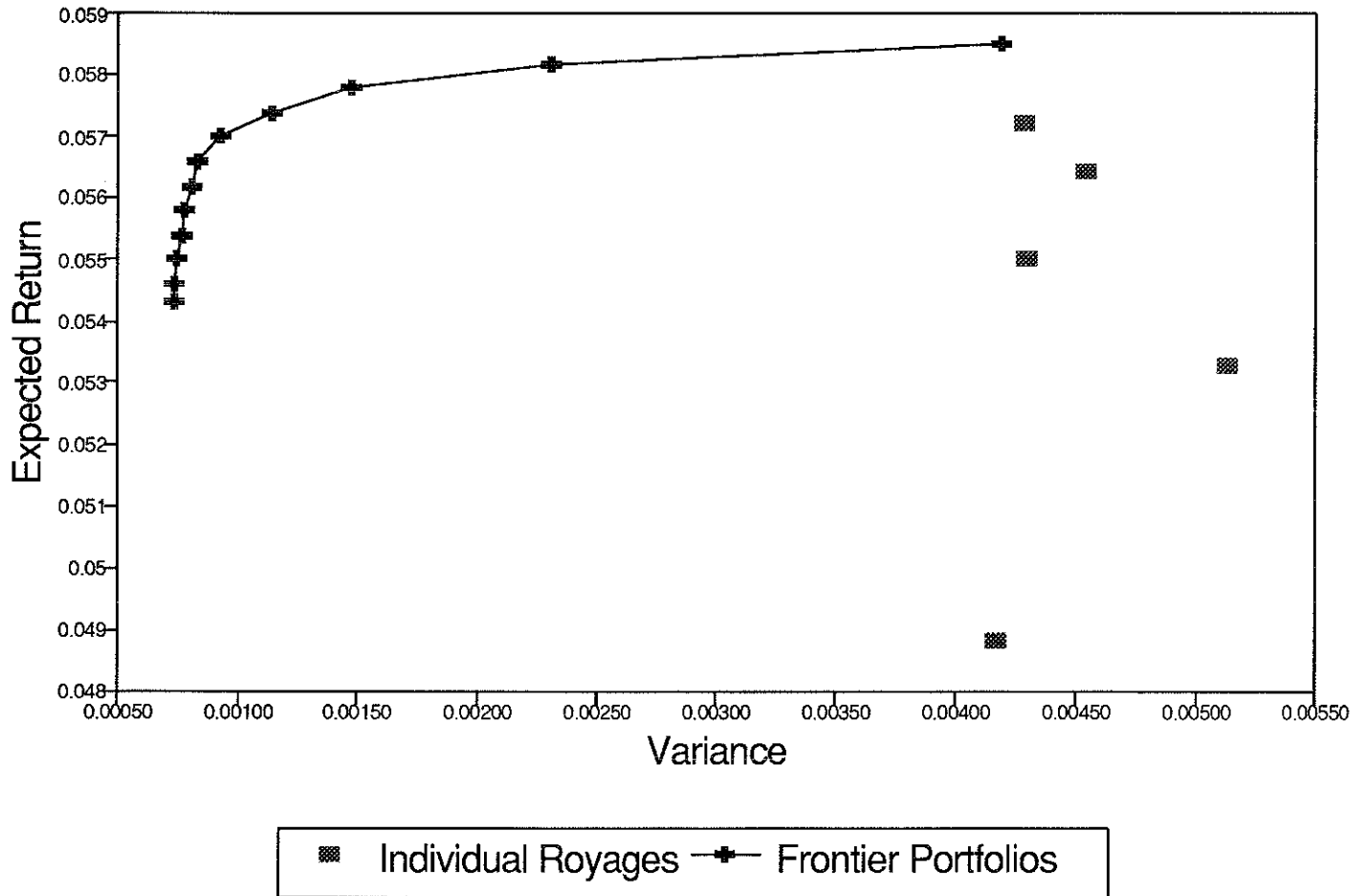
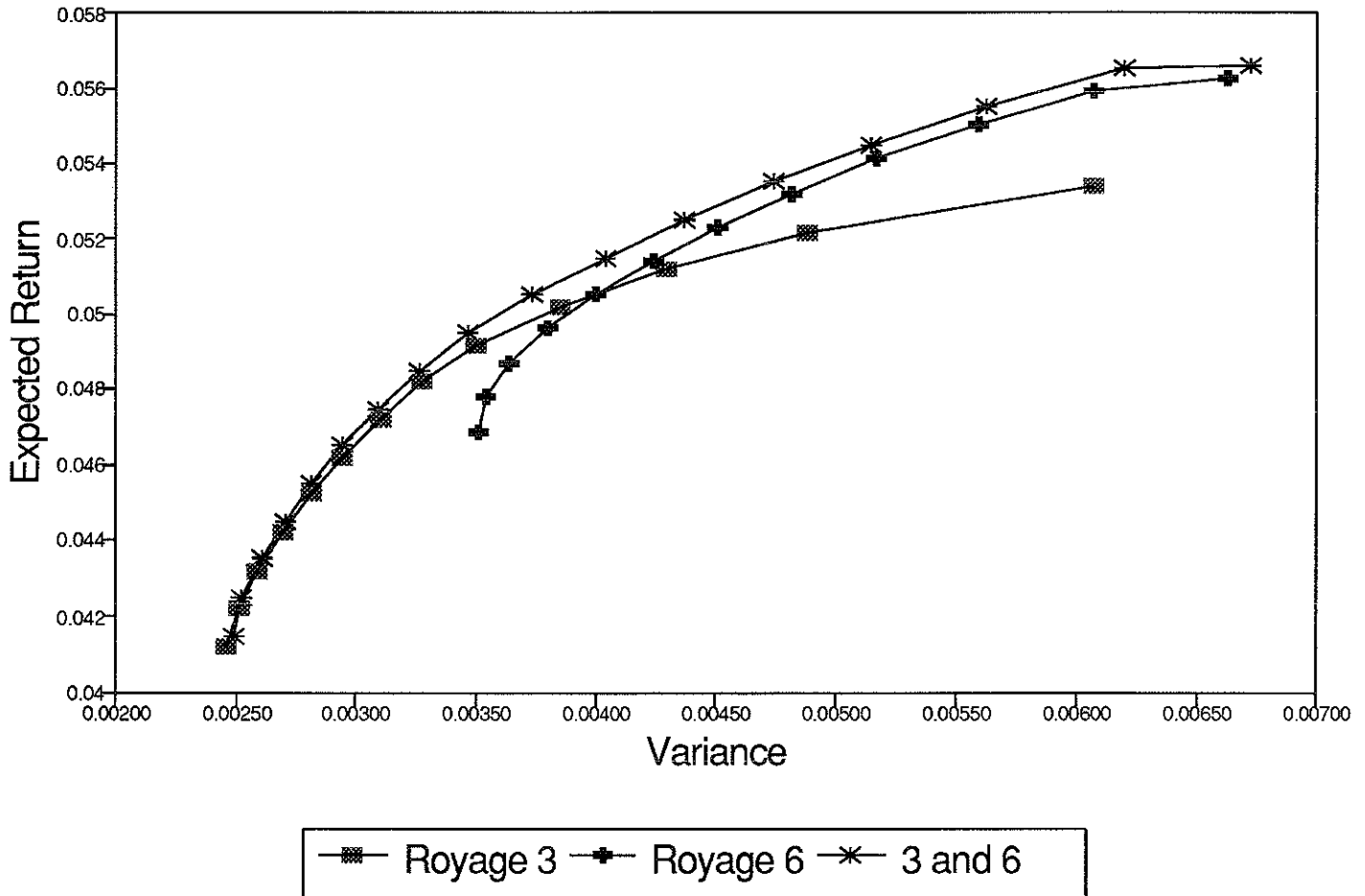


Figure 2. Mean-Variance Frontiers
Portfolios from Taques in Royages 3 & 6



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