HARVEST SHORTFALLS, GRAIN PRICES, AND FAMINES IN PRE-INDUSTRIAL ENGLAND

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HARVEST SHORTFALLS, GRAIN PRICES, AND FAMINES IN PRE-INDUSTRIAL ENGLAND[1]

Fresh data on English grain yields 1268-1480 are combined with revised price series to measure the frequency and scale of serious harvest shortfalls and estimate the elasticity of demand for cereals. Major food availability declines are shown to have been a significant component of most historical subsistence crises, as back-to-back shortfalls were of the worst famines. Although farmers did achieve some reduction in yield variance c.1400 to c.1800, serious harvest shortfalls long remained an unavoidable fact of economic life. England's progressive escape from famine therefore arose primarily from improved market integration coupled with more effective protection of the entitlements of the poor.

I. INTRODUCTION

How common were serious harvest shortfalls in Europe in the past? How often did they lead to subsistence crises and when, if ever, to outright famine? For want of hard demographic and agricultural output evidence, historians have often used extreme price variations to infer the frequency and magnitude of serious harvest shortfalls. Annual and even higher frequency cereal price series dating back to the Middle Ages are relatively plentiful. They are, however, by no means always easy to interpret in isolation, because the link between price and food supply in the past is poorly documented and controversial. Although high prices were usually

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associated with harvest deficits, they could also — to a greater or lesser extent — reflect intervening military, monetary, market, distribution, and demand-side factors. Nor did low prices always necessarily mean that harvests were adequate. The scale and duration of extreme price rises has also varied between crops, countries and time periods. How, for example, should the doubling of the real price of wheat in England between 1594 and 1597 be related to the three-fold rise in the real price of rice in Bengal in 1770 or the quadrupling of potato prices in Ireland between 1845 and 1847 (at a time when those of wheat and oats rose only 30 and 50 per cent)?

This paper combines new price and crop-yield datasets for medieval England to examine explicitly the relationship between harvests and prices at a relatively early stage in Europe's economic development. The price dataset has been assembled by Gregory Clark and incorporates and supersedes those constructed by both Henry Phelps Brown and Sheila Hopkins and by David Farmer.[2] The yield dataset has been assembled by Bruce Campbell and amalgamates the work of several other historians.[3] It relates exclusively to output on large-scale demesne farms employing hired and servile labor directly managed by or for lords and is geographically representative of the core regions of arable production in southern

[2] Clark's prices are available at: [WWW document] URL: *http://www.iisg.nl/hpw/data.php*. The correlations between year-to-year differences in the Clark and Farmer ("Prices and Wages," 1988 and 1991) series for 1269—1481 are 0.978 for wheat, 0.920 for barley, and 0.823 for oats. A revised and corrected Phelps Brown and Hopkins crop price series has also been made available by Munro, *Revisions*.

[3] Full details are given in Campbell, *Three Centuries.*

and eastern England, home to well over half the population.[4] Notwithstanding that manorial farms differed from smallholdings in terms of cultivation techniques, capital investment, and crop choice, high correlations between demesne yields and aggregate tithe receipts from all grain producers indicate that crop-specific year-to-year fluctuations in yields were broadly similar under both regimes.[5] Although the data range chronologically from the 1210s to the 1490s, annual coverage is only continuous from 1268 to 1480 and it is consequently upon the latter period that analysis is here concentrated.[6] The dataset comprises the single largest body of English yield observations prior to the advent of agricultural statistics in 1867 (livestock numbers and crop acreages) and 1884 (crop yields), and in volume,

[4] Campbell, *English Seigniorial Agriculture.*

[5] Campbell, "Four Famines".

[6] Postan (*Medieval Economy*, pp. 57-72) and Titow (*Winchester Yields*, pp. 12-33) attached great significance to the pre-1268 yield data, almost all of it from the vast estates of the bishops of Winchester in southern England, since the exceptionally high yields ostensibly achieved on some demesnes appeared to support their hypothesis that arable husbandry subsequently succumbed to a productivity crisis brought on by over-cultivation and a mounting agronomic imbalance between grassland and tillage. Nevertheless, it is now clear that the veracity of many of these early yield ratios is suspect. Not only are yields for some demesnes in some years unnaturally high but they are also out of kilter with corresponding price levels. Using the predicted values gained from running NY_i (net yield in year i) on price in year $i+1$ and year i for 1268-1493 gives the following margins above $e(NY_i)$ for the out-of-sample outlying years on which price data are available:

	Year and Crop							
	1244 (Wheat)	*1244 (Barley)*	*1255 (Wheat)*	*1257 (Barley)*	*1260 (Wheat)*	*1262 (Barley)*	*1262 (Oats)*	*1267 (Wheat)*
% > $e(NY_i)$	51	128	52	46	57	80	50	52

The explanation probably lies in some, as yet unidentified, ambiguity in contemporary accounting procedures which has artificially inflated the harvested totals, such as the lumping of grain received as tithes with that harvested from the demesne.

consistency and reliability eclipses that assembled for the eighteenth and nineteenth centuries from farm accounts by Michael Turner, John Beckett, and Bethanie Afton.[7]

The outline of the paper is as follows. First, the recent literature on the extent of major subsistence crises in pre-industrial England is reviewed (Part II). That literature can be interpreted as a debate about the nature of the demand for staple foodstuffs, and so in Part III the crop-yield and price data are employed to shed light on Charles Davenant's famous 'law', which linked harvests and prices in late seventeenth-century England. Part IV addresses the issue of crop variability directly, confirming both its severity in the medieval era and its gradual attenuation in following centuries. Part V then analyzes and contrasts two particularly severe harvest shocks, those linked to the Great Famine of 1315-17 and the Black Death. Part VI concludes.

II. THE 'ULTIMATE CHECK' IN PRE-INDUSTRIAL ENGLAND

Malthus believed that Europe had long been less subject to the 'ultimate check' than the rest of the globe, asserting that while untold millions of European lives had been blighted by malnutrition, 'perhaps in some … states an absolute famine may never have been known'.[8] England is a case in point. Andrew Appleby and Richard Hoyle have described what is usually deemed to have been that

[7] Turner, Beckett, and Afton, *Farm Production*.

[8] Malthus, *Principle of Population*, Book II, chapter 13. Fogel, "Escape from Hunger," similarly doubts the historical importance of famine but emphasizes the significance of malnutrition.

country's last significant subsistence crisis, which was confined to the upland north-west of the country in the 1620s and registered only a modest demographic impact at a national scale.[9] Steve Hindle believes that a run of bad harvests again brought England to the brink of famine in 1647-50 and a case can be made for the recurrence of subsistence problems in both 1727-9 and 1740-2.[10] The latter, in fact, was the last occasion in English demographic history when a negative rate of population increase arose from the elevation of deaths above births at a time of acute food scarcity; marriage rates, too, were depressed — a sure sign of economic hardship.[11] Nevertheless, the situation in England was far less serious than in neighboring Ireland, where the 1740-2 crisis ranks as a major famine, which, on David Dickson's reckoning, may have reduced the population by as much as 15-20 per cent.[12]

That eighteenth-century Ireland was more susceptible to famine than England reflected the less developed state of its economy, the lack of any effective infrastructure for supplying relief to the victims of the massive food availability decline (since, unlike England, Ireland lacked a nation-wide poor law), and, above all, the lesser effectiveness of its government. The last bears out Robert Fogel's point that by the eighteenth century it was within the power of European

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[9] Appleby, *Famine*; Hoyle, "Famine." See also, Laslett, *World We have Lost*, pp. 119-25; Slack, *Poverty and Policy*, pp. 45-6, 48-50.

[10] Hindle, "Dearth"; Campbell, "Four Famines".

[11] Wrigley and Schofield, *Population History*, pp. 531-5.

[12] Dickson, *Arctic Ireland*, p. 69.

governments to avert full-scale famines.[13] Thus, as John D. Post has demonstrated, although this was a subsistence crisis of pan-continental dimensions (since the abnormal weather conditions responsible for the supply-side failure had the whole of northwestern Europe in their grip), some governments coped far better with the crisis than others.[14] Thereafter, although extreme weather events recurred, England, and a growing number of European countries, remained effectively famine free (with Ireland one of the last to join the club).[15] When in 1800-01, at the height of the Napoleonic blockade, the English harvest failed and grain prices soared, no major mortality crisis ensued. Instead, it was poor relief and fertility controls that took most of the strain.[16]

In Fogel's view the bulk of these historical subsistence crises arose more from 'failures in the system of food distribution' than to natural calamities *per se*.[17] It is therefore tempting to link Europe's progressive escape from subsistence crisis and famine to the more effective functioning of grain markets, as a result of better arbitrage between markets and between good and bad years (a process in which

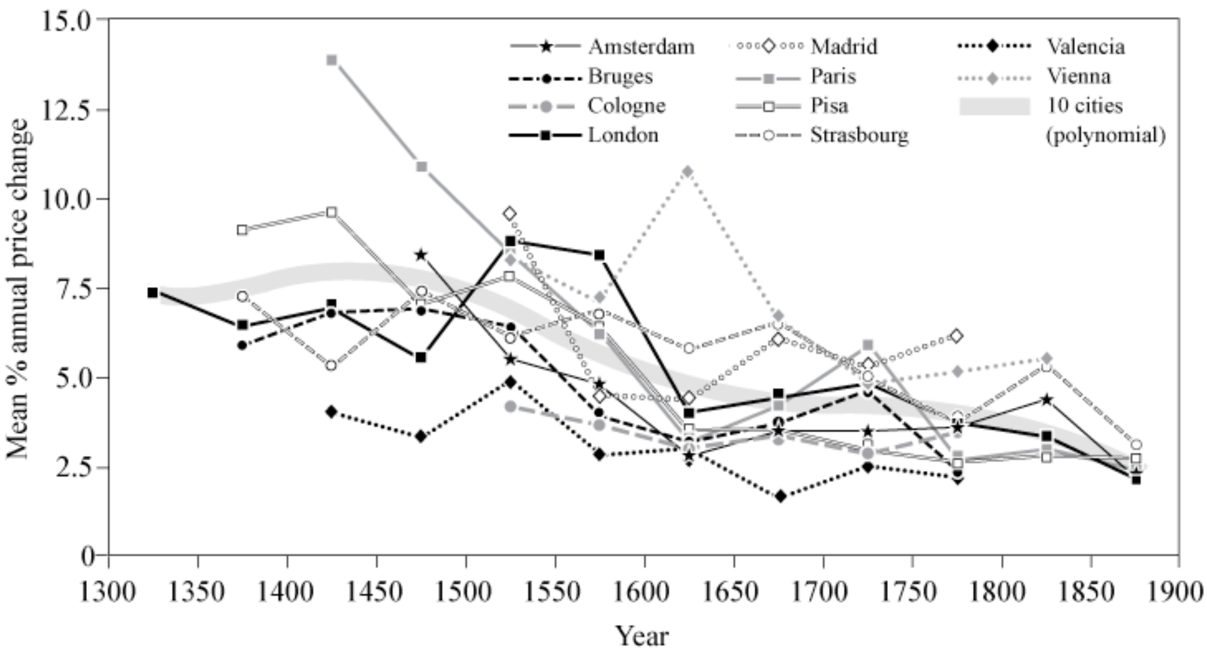
[13] Fogel, "Second Thoughts."

[14] Post, *Food Shortage*, pp.142-201. The years 1740-2 stand out in dendrochronologies from both the northern and southern hemispheres as years of minimum tree growth, which bears clear testimony to the exceptional climatic conditions then prevailing: Baillie, "Abrupt Environmental Change," p. 56; Baillie, "Dendrochronology," pp. 105-7, 112-15, 119.

[15] On the crisis of the 1840s see Ó Gráda, Vanhaute, and Paping, *When the Potato Failed*; Baillie, "Bad for Trees."

[16] Wells, *Wretched faces*; Campbell, "Four Famines."

[17] Fogel, *Escape from Hunger*, p. 53-54.



Note: the mean annual difference is calculated as the mean percentage year-to-year change in the logged wheat price, averaged over half-centuries; the prices for Amsterdam, Bruges, Cologne, London, Madrid, Paris, Pisa, Strasbourg, Valencia, and Vienna are those given in Allen and Unger, *Allen—-Unger Database.*

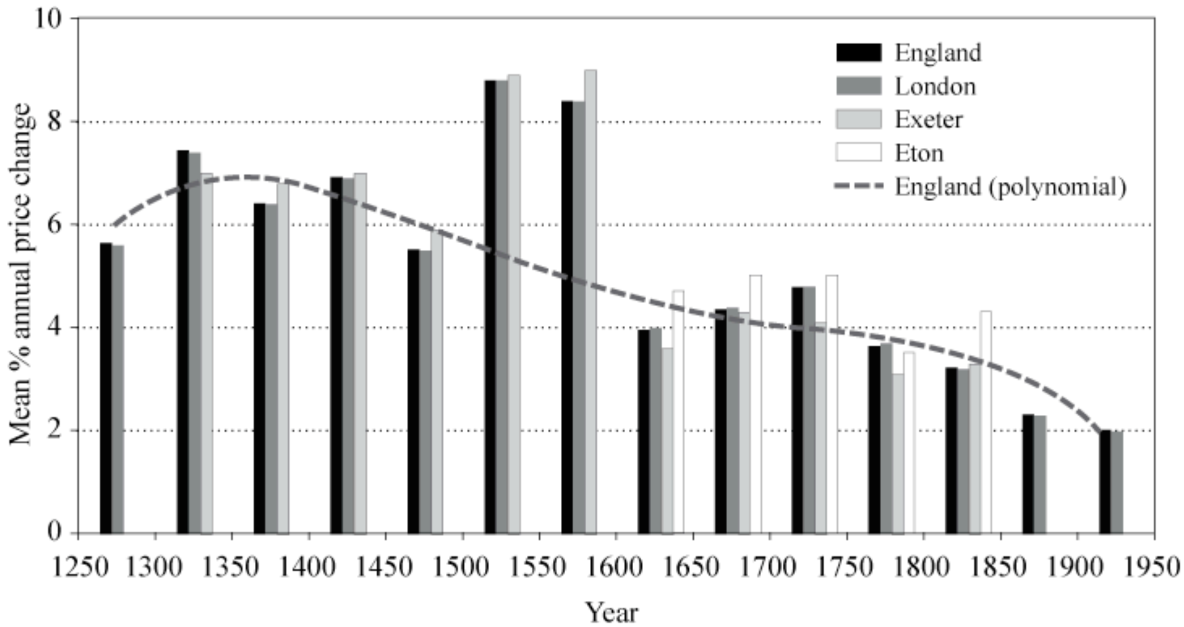
Figure 1: Wheat price: mean annual percentage change in ten European urban markets, 1300-1899.

governments themselves were active agents).[18] Analysis of the changing magnitude of year-to-year variations in wheat prices for a sample of ten European cities from the fourteenth to the nineteenth centuries certainly suggests that from the late fifteenth century markets for the premier bread grain were becoming more integrated. In many of Europe's major maritime cities late-medieval levels of price

[18] Persson, *Grain Markets*, pp. 91-113; Epstein, *Freedom and Growth*, pp. 155-67 (and especially Figure 7.3).

variability had already been substantially reduced by the mid-seventeenth century and by the end of the eighteenth century they had mostly been halved, leaving only limited scope for further reductions following the technological advances of the industrial revolution (Figure 1). Price variations in the interior cities of Vienna (where war had a major negative impact on price variations), Strasbourg, and Madrid remained higher but eventually followed the same trend. Across all ten cities, the magnitude of annual wheat-price variations was at a temporal peak during the first half of the fifteenth century, when grain markets were presumably least integrated. Thereafter, the magnitude of annual wheat-price variations fell to 55 per cent of that peak by the early seventeenth century and then to 30 per cent by the close of the nineteenth century, trends which are consistent with the thesis that grain markets were improving in efficiency.

In London, in contrast to most other major cities, the magnitude of annual wheat-price variations actually increased during the price revolution of the sixteenth century (Figures 1 and 2). It then rapidly subsided to a level in the seventeenth century a third lower than that prevailing in the famine-prone early fourteenth century, before declining to a low point at the opening of the twentieth century that was barely a quarter of that prevailing six centuries earlier. Was the whole of this substantial fall, the bulk of it occurring after c.1590, the product of improvements in market efficiency aided and abetted, when necessary, by government action? Certainly, adoption at the instigation of central government of a nation-wide poor law system must have done a great deal to alleviate distribution



Note: the mean annual difference is calculated as the mean percentage year-to-year change in the logged wheat price, averaged over half-centuries; the prices for England, London, Exeter, and Eton are those given in Allen and Unger, *Allen—-Unger Database*.

Figure 2: Wheat price: mean annual percentage change in England and three English urban markets, 1260-1914.

problems and protect the food entitlements of the poorest and most vulnerable members of English society at times of greatest scarcity.[19] Very likely this had the secondary benefit in years of acute scarcity of restraining the inflationary pressure that would otherwise have arisen from inelastic demand. The lack of any pronounced demographic dynamic between 1650 and 1750 may also have helped keep annual grain-price variations within modest bounds, a development reinforced

[19] Slack, *Poverty and Policy*; Hindle, *On the Parish?*; Smith, "Social Security"; Kelly and Ó Gráda, "Living Standards and Mortality".

by the rising productivity of domestic agriculture manifest in England's emergence after 1700 as a net grain exporter on a significant scale.[20] As English farmers adopted the package of measures that constituted the so-called 'agricultural revolution', namely greater agricultural specialization, enclosure, improved rotations, and the sowing of higher-yielding seed, is it possible that they may also have succeeded in limiting the variability of harvests and, thus, the magnitude of annual price variations?[21] Or did nature continue to levy a periodic heavy toll on domestic output?

Fogel has claimed that historians' reliance on price data may have led them to overestimate the scale of food availability declines.[22] Yet the data required to analyze the relationship between price and food supply directly are rare before the nineteenth century, particularly in famine-prone regions. Karl-Gunnar Persson has lamented the scarcity of 'data on either prices or quantity deviations for a given region in the early modern period', and this explains why he and Fogel rely mainly on nineteenth- and early twentieth-century English, French and Swedish crop-yield data in their analyses of the variability of food supply in early modern Europe.[23] Persson is nevertheless less sanguine than Fogel on the resistance of that supply to exogenous environmental shocks and endorsement of his position has recently

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[20] Ormrod, *English Grain Exports*, pp. 96-7. See also Apostolides, Broadberry, Campbell, van Leeuwen, and Overton, "English Agricultural Output."

[21] Allen, *Enclosure and the Yeoman*; Overton, *Agricultural Revolution*.

[22] Fogel, "Second Thoughts," pp. 253-55.

[23] Persson, *Grain Markets*, p. 53; Fogel, "Second Thoughts."

been provided by Rafael Barquin, who has cast doubt on the validity of the statistics upon which Fogel based his views.[24]

III. DAVENANT'S LAW AND HARVEST SHORTFALLS

Analysis of the relationship between proportionate harvest shortfalls and resultant increases in the price of wheat seems to have begun with Charles Davenant's celebrated table purporting to describe the market for wheat in seventeenth-century England.[25] The schedule is well captured by $Q = 1.00P^{-0.403}$, where P is price, Q is quantity demanded, and –0.403 is the price elasticity of demand.[26] Since Davenant lacked aggregate agricultural data to build upon, his table must nevertheless be considered no more than at best an informed conjecture. The elasticity estimate implicit in his table lies roughly half way between the figure of –0.183 derived by Fogel from English price and yield data and the –0.6 or so suggested by Persson on the basis of French and Swedish data.[27] Barquin, however, has tested Fogel's result using the same data and method and been unable to replicate it. In his view 'following his [i.e. Fogel's] procedure faithfully, the elasticity of demand for wheat in Great Britain would be

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[24] Barquin, "Elasticity of Demand."

[25] It is often incorrectly ascribed to Gregory King.

[26] Stigler, *Essays*, p. 215 fn. 32. Philip Wicksteed (see Stigler, *Essays*, p. 214 fn. 30) found that the equation — $60p = 1{,}500 - 374q + 34q^2 - q^3$ — where normal q is 10 and normal p is 1, provided an exact fit for Davenant's schedule, while Wrigley, "Reflections on Corn Yields," pp. 92-5, reports two other formulations, by Jevons and Bouniatian.

[27] Fogel, "Second Thoughts," p. 252; Persson, *Grain Markets*, p. 54.

-0.36 (0.08 / 0.22)', which is fairly close to the value implied by Davenant.[28] That the price elasticity of wheat was substantially lower in Great Britain than in contemporary Sweden or France might then reflect the fact that in the case of normal goods — i.e. goods with an income elasticity of demand above zero — the price elasticity of demand should be lower in richer than in poorer economies.

Fogel's probably erroneous estimate supported his conviction that very high prices in Europe in the early modern era did not imply huge harvest shortfalls; in the case of England he concludes that 'there does not appear to have been a single year after *c*.1500 in which aggregate supply of food was too low to avoid a subsistence crisis'.[29] He further buttressed his case for a low demand elasticity with demographic data from Wrigley and Schofield, which suggest that mortality in pre-industrial England was high but not subject to huge year-to-year fluctuations.[30] Since low elasticities meant that high prices did not imply huge harvest shortfalls, scope was left for public action to redistribute available food supplies. This led Fogel to argue (in the spirit of Amartya Sen's *Poverty and Famines*) that any major European subsistence crises and famines in the early modern era were less due to food availability declines than to public inaction or mis-governance. By contrast, Persson's estimates imply that serious harvest shortfalls were a reality in early modern Europe, and so resuscitate the historical significance of subsistence crises

[28] Barquin, "Elasticity of Demand," p. 251.

[29] Fogel, "Second Thoughts," p. 255; but compare Appleby, *Famine*; Hoyle, "Famine"; Campbell, "Four Famines."

[30] Wrigley and Schofield, *Population History*.

and rationalize the need for pro-active public policy in a context where markets still functioned slowly and natural hazards sporadically had a major impact upon the output of staple foodstuffs.

Whether output is measured gross or net of on-the-farm deductions of seed and fodder has a significant bearing upon estimated levels of elasticity. Fogel, as revised by Barquin, relies on late-nineteenth century English agricultural crop yields, which refer to gross output. As Wrigley has noted, whether Davenant's data refer to gross or net output is not quite clear.[31] If (as seems more likely) they are taken to be net of seed requirements, then an estimate based on gross output that assumes an average yield ratio of five-to-one gives an elasticity of -0.31, instead of the -0.40 derived from the same data net of seed (seed ratios of four-to-one and ten-to-one would mean respective gross output elasticities of -0.29 and -0.35). Barquin's revised elasticity estimate of -0.36 for gross output thus implies an elasticity in excess of Davenant's -0.4 for net output. Both Fogel and Persson use the elasticity measure:

$$\varepsilon = -\sigma_q/\sigma_p \qquad [1]$$

where ε is the price elasticity of demand, and the σs are the standard deviations of output (q) and price (p). Fogel, as revised by Barquin, divides a measure of σ_q (0.082, computed from the proportionate deviation from trend in official English wheat yield data for 1884-1913) by one of σ_p (0.22, based on English price data for

[31] Wrigley, "Reflections on Corn Yields," pp. 94-7.

1540-1840) to obtain an elasticity of –0.37.[32] Since [1] assumes that price and quantity are perfectly correlated, the true elasticity is likely to be lower, and so Fogel claims that his is an upper-bound estimate of the true elasticity.[33]

Crop	*Gross Yield*			*Net Yield*			*Prices*		
	(1) Mean	(2) σ	(2)/(1)	(3) Mean	(4) σ	(4)/(3)	(5) Mean	(6) σ	(6)/(5)
Wheat	9.79	2.01	0.205	7.30	1.96	0.268	0.68	0.2024	0.298
Barley	13.18	2.38	0.181	9.22	2.25	0.244	0.44	0.1137	0.258
Oats	10.14	1.88	0.185	6.80	1.63	0.240	0.25	0.0583	0.233

Note: yield data from Campbell, *Three Centuries*; price data from URL: *http://www.iisg.nl/hpw/data.php*. The price series have been de-trended and the standard deviations estimated using the Hodrick-Prescott filter.

Table 1: English yields and prices, 1268-1480.

Is it justifiable to use later data as a proxy for the variability of output in early modern Europe? Table 1, derived from the new dataset of English yields 1268-1480 described above, suggests not. Further, it demonstrates that significant under-estimation can occur if insufficient account is taken of crops other than wheat, especially oats. Thus, applying elasticity measure [1] to the standard deviations of net yields and prices given in columns (6) and (9) in Table 1 produces elasticity estimates for wheat, barley and oats of respectively -0.90, -0.95, and

[32] Barquin, "Elasticity of Demand," p. 251.

[33] Likewise, Persson's estimates are upper-bound estimates of the true elasticity, to the extent that they do not attempt to correct for the likely less-than-perfect correlation between prices and yields.

-1.03.[34] Using gross yield — column (3) — generates the lower values of -0.69, -0.70, and -0.79, but even these are substantially above the maximum estimates based upon nineteenth-century Swedish and French data offered by Persson and roughly double Barquin's revised estimate for nineteenth-century Britain.[35] They are, however, broadly comparable with the latter's figure of -0.8 calculated for wheat from French and Swiss tithe data spanning the sixteenth to eighteenth centuries and confirm his conclusion that price elasticities for the gross output of wheat in the early modern period normally lay within the range -0.5 to -0.8.[36]

Alternatively, Table 2 reports estimates of the elasticity of demand calculated using variants of:

$$\ln(q) = a + b.\ln(p) + u \qquad [2]$$

where b is the elasticity. These combine the price series and the net yield data, lagged one year.[37] These elasticities are generally lower than those obtained using elasticity formula [1], especially for barley and oats, and are more consistent with those implied by Davenant's table. They imply that a doubling of wheat prices meant a harvest shortfall of more than one-half. Breaking the dataset at the Black Death (1349) reveals no striking difference between the two periods in the case of

[34] The price series have been de-trended and the standard deviation estimated from deviations from trends used.

[35] Using Farmer's price data generates elasticities of -0.61, -0.67, and -0.88 (for gross yields) for wheat, barley, and oats, respectively, and -0.80, -0.91, and -1.14 (for net yields).

[36] Barquin, "Elasticity of Demand," pp. 263-64.

[37] On the principle that yields in year t determined prices in year $t + 1$.

Period & crop	Estimated price-elasticity of demand:	
	OLS method	Error Correction method
1268-1480:		
Wheat	-0.786	-0.638
Barley	-0.452	-0.365
Oats	-0.331	-0.287
1268-1349:		
Wheat	-0.821	-0.659
Barley	-0.398	-0.299
Oats	-0.191	-0.123
1350-1480:		
Wheat	-0.760	-0.581
Barley	-0.498	-0.466
Oats	-0.458	-0.423

Note: the elasticities are for yields net of seed. The OLS estimates were calculated using the ratios of $\ln(q_t/q_{t-1})$ *and* $\ln(p_t/p_{t-1})$. The ECM used was: $\Delta \ln(q_t) = a + \Delta\, d(\ln(p_t) + c.\ln(q_{t-1})$. The yield data are from Campbell, *Three Centuries*, and the price data from URL: http://www.iisg.nl/hpw/data.php.

Table 2: England 1268-1480, estimated price-elasticity of demand.

wheat, in contrast to an increase in the elasticities of barley and especially oats.[38] Perhaps rising living standards in the wake of the Black Death had reduced the demand for barley and oats and thereby raised their income elasticities, although this explanation works better for oats than barley since the latter benefited from a

[38] In line with Persson, *Grain Markets*, pp. 55-62 (compare Fogel, “Second Thoughts,” pp. 252-55), it is assumed here that carry-over stocks of grain were negligible; England’s net foreign trade in grain is also assumed to have been negligible in this period.

growing thirst for ale brewed from malted barley.[39] The yield data also confirm that in the worst harvests of all — in the case of wheat, 1316, 1339, 1349, 1350, 1351, 1420, 1438, and 1477 — less than three-fifths the trend value of the net yield were returned. The effects of such dismal harvests must have been felt throughout the economy and impacted in different ways upon all social classes.

Notwithstanding the concentration upon wheat in much historical analysis, oats and barley were also significant crops in medieval and early modern England.[40] Both were better suited to brewing than wheat, were staple ingredients of the coarser and cheaper grades of bread, were widely consumed as pottage by the poorer classes, and oats in particular was a staple fodder crop. Whereas wheat was invariably sown in the autumn, most barley and virtually all oats were sown in the spring. These spring grains were therefore largely unaffected by a bad autumn or winter and might even be sown as a replacement for wheat or rye if the latter looked like failing as a result of harsh winter conditions. Since these grains differed in their fertility demands upon the soil, they also formed complementary components of the more elaborate rotations as exemplified by the classic three-course rotation of winter crops, spring crops, and then a full year's recuperative fallow. Of these three staple grains wheat may have been the most highly priced

[39] Galloway, "Driven by Drink?" Compare Le Roy Ladurie (*Peasants of Languedoc*, pp. 44-47) on the Black Death's impact on the quality of bread and wine consumed in France.

[40] From 1300 to 1850 barley and oats consistently accounted for 32-48% of national grain output net of seed and fodder and 42-58% by volume: Broadberry, Campbell, Klein, Overton, and van Leeuwen, "British Economic Growth."

	Between-crop correlation coefficients:					
A: 1268-1480	Net Yields [1268-1480]			Prices [1269-1481]		
	Wheat	Barley	Oats	Wheat	Barley	Oats
Wheat	1.000			1.000		
Barley	0.357	1.000		0.793	1.000	
Oats	0.169	0.416	1.000	0.744	0.850	1.000
B: 1268-1349	Net Yields [1268-1349]			Prices [1269-1350]		
	Wheat	Barley	Oats	Wheat	Barley	Oats
Wheat	1.000			1.000		
Barley	0.403	1.000		0.956	1.000	
Oats	0.284	0.384	1.000	0.839	0.862	1.000
C: 1350-1480	Net Yields [1350-1480]			Prices [1351-1481]		
	Wheat	Barley	Oats	Wheat	Barley	Oats
Wheat	1.000			1.000		
Barley	0.314	1.000		0.676	1.000	
Oats	0.154	0.436	1.000	0.661	0.849	1.000

Note: yield data from Campbell, *Three Centuries*; price data from URL: http://www.iisg.nl/hpw/data.php.

Table 3: England 1268-1480, between-crop yield and price correlations.

and widely traded, nevertheless only oats was capable of being grown in virtually all farming regions since it was tolerant of the widest range of growing conditions. In fact, in many upland areas it was almost the only grain grown. To overlook the oats harvest is therefore to ignore the nation’s most universal cereal. Oats was also far more affordable than wheat and its harvest was consequently more material to the nutrition of the poor.

Sowing wheat in the autumn and almost all oats in the spring also offered a non-negligible element of insurance to cultivators and consumers, as captured by the relatively low, albeit positive, correlation between wheat and oats yields (Table 2).[41] The correlation between first differences in net yields was +0.06. As is to be expected, year-to-year changes in oats and barley yields were more highly correlated (+0.30). Growing and harvesting conditions had to be exceptionally good or bad for the yields of winter and spring grains to have been similarly affected. Tellingly, the correlation coefficient between oats and wheat yields reaches +0.391 over the watershed period 1314-1351, compared to only +0.169 over the entire period 1269-1480. There is a clear implication that during these years environmental conditions were powerfully in the ascendant with the result that the yields of winter and spring grains became strongly rather than weakly correlated.[42] As a result producers forfeited many of the insurance benefits of cultivating both types of grain; this mattered little when both did well, but a lot when both fared badly. As Table 3 reveals, movements in the prices of the three crops were normally much more highly correlated, suggesting the integration of markets across, and inter-changeability of demand between, cereals.

[41] The standard deviation of the unfiltered wheat yield series for the 1270-1475 period is 22.6. Assuming weights of 0.5 for wheat and 0.25 each for barley and oats produces a standard deviation for ‘cereals’ of 17.8, or nearly 18 per cent less.

[42] Campbell, “Physical Shocks.”

IV. HOW COMMON WERE 'BAD' YEARS?

W. G. Hoskins, in a pioneering attempt to infer harvest quality from English grain prices, reckoned that for the period 1480—1619 'out of the total of 140 harvests…the really "bad harvests" numbered 24, or slightly more than one in six'.[43] This appears to corroborate the view of Elizabethan Dr John Hales that one harvest in seven was a failure.[44] A century and a half later, Thomas Short proposed that seriously deficient harvests occurred every 7½ years and then, in 1846, demographer William Farr claimed on the evidence of accounts contained in medieval and early modern chronicles that he had discovered the 'law governing scarcities in England', namely, ten years of famine per century before AD 1600.[45] The geographical and temporal spread of famines in Cornelius Walford's (1879) chronology based on similar sources — three-quarters of the total in Europe, over half of the remainder in India — show why such claims cannot be taken too seriously.[46] They also underline the difficulties in determining the frequency and geographical extent of bad harvests and famines in the past.[47]

The period covered by the medieval crop-yields database witnessed in 1315-17 one of Europe's greatest famines and, c.1400-20, spanned what has

[43] Hoskins, "Harvest Fluctuations," pp. 29-30.

[44] Cited in Hoskins, "Harvest Fluctuations," p. 30.

[45] Short, *New Observations*, vol. II, p. 206 (Short's opinion was invoked by Malthus in later editions of *Principle of Population*); Farr, "Influence of Scarcities."

[46] Walford. *Famines of the World*.

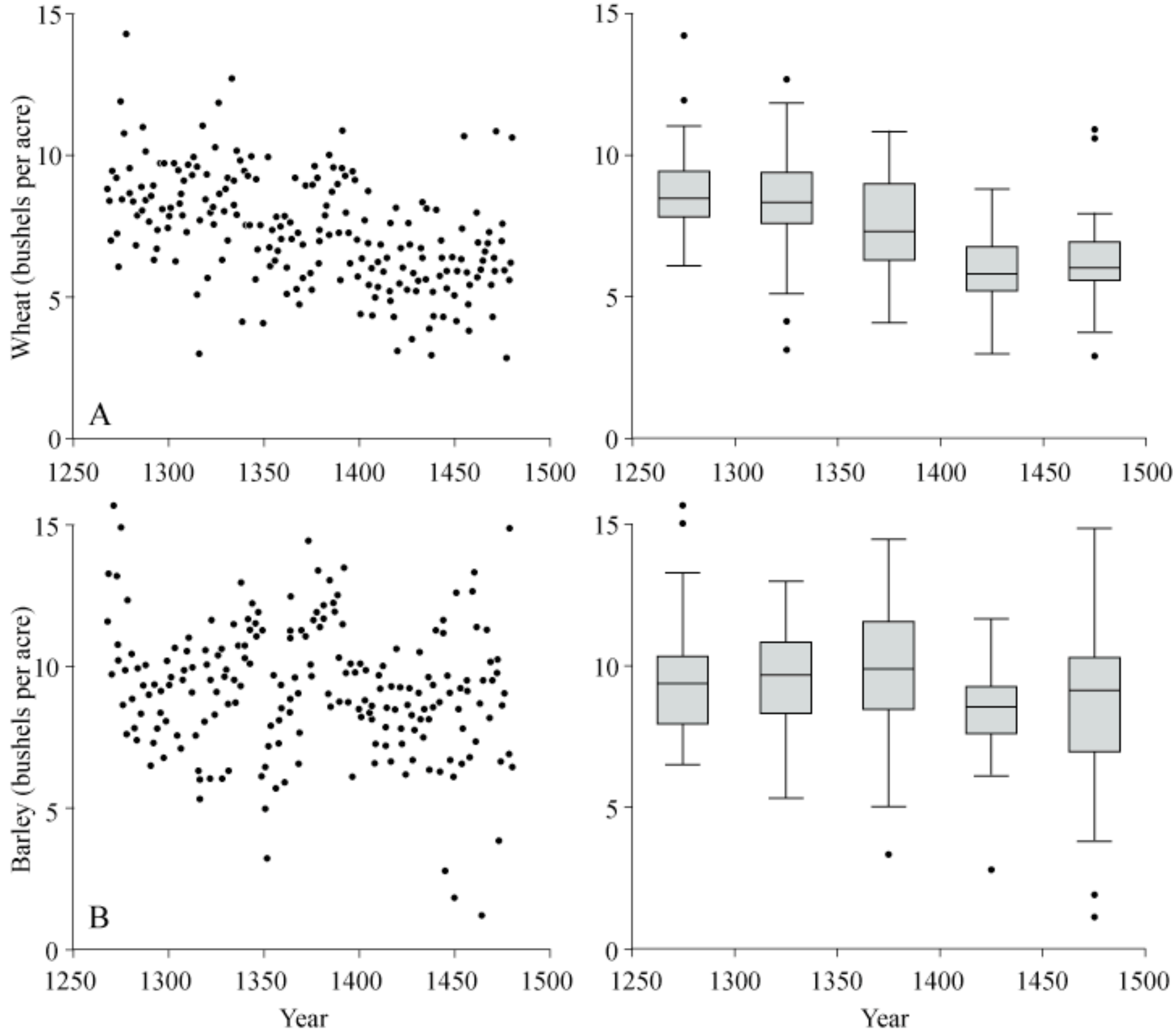
[47] Ó Gráda, "Making Famine History."

recently been claimed to have been the single greatest atmospheric change of the second millennium A.D.[48] This was when, following a period of marked environmental instability, the relatively benign conditions of the so-called Medieval Warm Period finally gave way to the agriculturally more challenging conditions associated with the Little Ice Age.[49] Figure 3 describes the variability in the yields of the three main cereal crops and the composite wheat-barley-oats (W-B-O) yield for the 1268-1480 period. The scatter-plots convey the extent of the variability and identify extreme years such as 1278 and 1316 for wheat and 1350, 1351, and 1476 for oats. The box-plots illustrate broader trends and demonstrate that net yields per acre were generally lower in the fifteenth than in the fourteenth century. Maybe this was because in this post Black Death era of scarce and dear labour demesne managers were cultivating the land less intensively and this more than offset the compensatory productivity benefits of taking inferior demesne land out of cultivation and stocking more livestock.[50] Possibly also growing and harvesting conditions may have become less favourable.

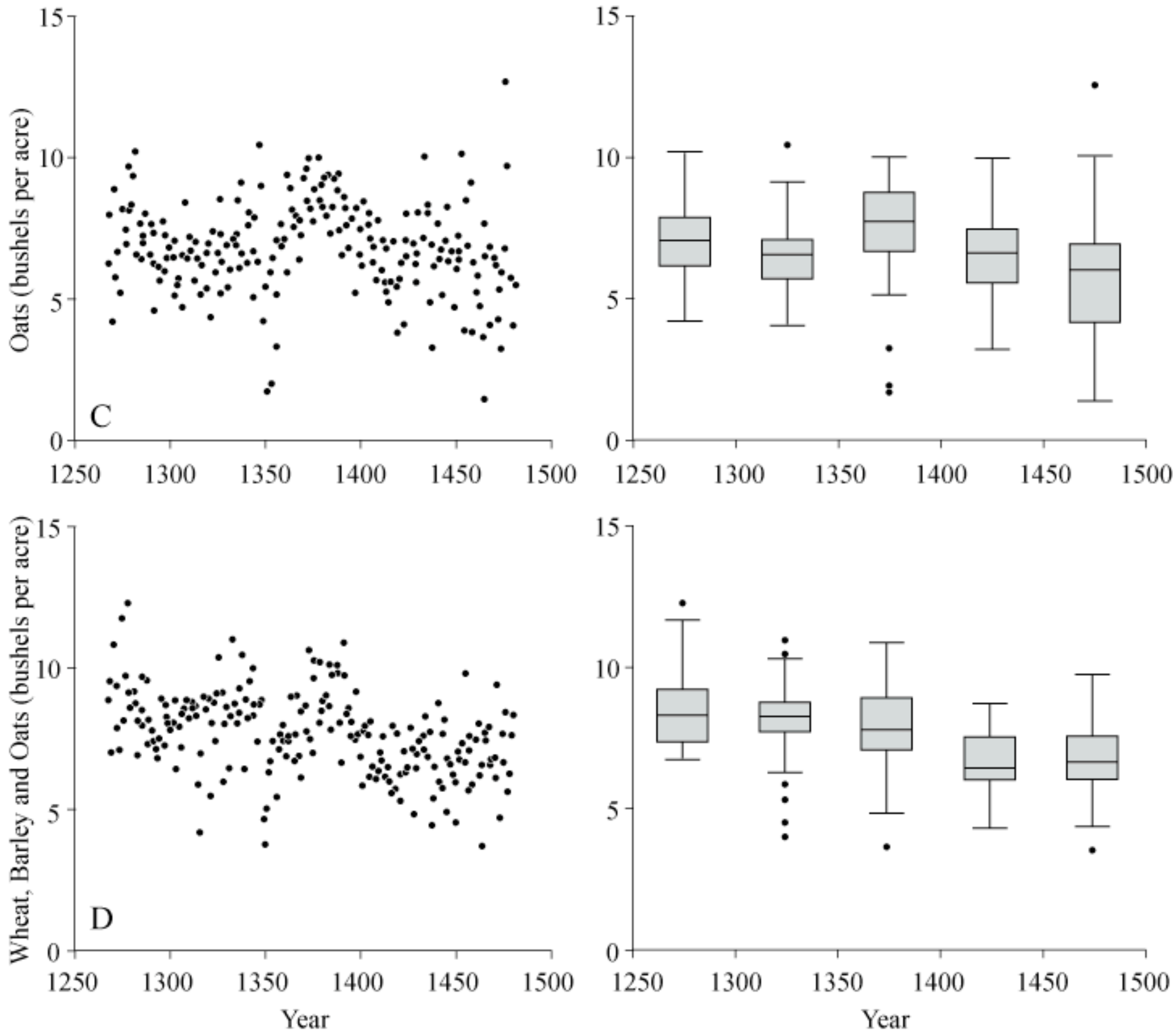
[48] Kershaw, “Great Famine”; Jordan, *Great Famine*; Meeker and Mayewski, “Atmospheric Circulation”; Dawson, Hickey, Mayewski, and Nesje, “North Atlantic Climate Changes,” pp. 426-7.

[49] Campbell, “Nature as Historical Protagonist.” Both the scale and economic significance of these climate variations remain matters of debate, however: see Kelly and Ó Gráda, “Little Ice Age.”

[50] For evidence of increased stocking densities, reduced sown acreages, and reduced labour inputs see Farmer, “Westminster Abbey Manors”; Farmer, “Winchester Manors”; Campbell, “Agricultural Progress,” pp. 38-9; Stone, *Decision-Making*, pp. 109-13.



Certainly, the variability of yields seems to have shifted over this long period, although not in a simple or consistent way. Wheat yields were subject to greatest variation in the half-century 1350-1399 (when a succession of below average harvests from 1350 to 1375 was succeeded by a run of the most bountiful harvests on record), while barley and oats yields both fluctuated most after 1450 (when the



Note: yield data from Campbell, *Three Centuries.* Each box plot marks the maximum, upper-quartile, median, lower-quartile, and minimum values; extreme outlying values are marked separately.

Figures 3A—D. Scatter-plots and box-plots of English net grain yields per acre, 1268-1480.

data are at their thinnest and least representative). Yields overall were somewhat more variable in the late thirteenth and the fourteenth centuries than in the first half of the fifteenth century, which might be linked to the mounting instability of weather conditions down to the mid- fourteenth century highlighted in recent environmental research.[52] The increasing unreliability of yields thereafter was especially evident in the case of oats and is in marked contrast to the striking stability of oats yields in the first half of the fourteenth century. While it is tempting to attribute such differences to the influence of the weather, not least because weather conditions seem to have changed in subtle but significant ways over the course of the fourteenth and fifteenth centuries, climatic differences alone can hardly account for the fact that, as reconstructed from farm-level data, medieval yields of wheat and barley were three times, and medieval oats yields more than four times, as variable as modern (post-1884) English/British yields documented by the official agricultural statistics (Table 4).

Table 4 compares the coefficients of variation in *gross* yields of wheat, barley, and oats in medieval England with those in nineteenth- and twentieth-century Great Britain, Germany, France, and Sweden. The principal differences thereby revealed — notably the conspicuously greater variability of medieval English yields compared with all modern yields and the lesser variability of modern British yields, especially of barley and oats, compared with those of Germany, France, and Sweden — suggest that a key unsung achievement of English/British farmers and their seed suppliers between the Middle Ages and the late nineteenth century may

[52] Dawson, Hickey, Mayewski, and Nesje, "North Atlantic Climate Changes"; Campbell, "Physical Shocks."

Crop	Period	Country	(1) Mean	(2) σ	(2)/(1)
Wheat	1268-1480	England	9.79	2.01	0.205
Barley	1268-1480	England	13.18	2.38	0.181
Oats	1268-1480	England	10.14	1.88	0.185
Wheat	1750-1850	England	22.61	2.80	0.123
Barley	1750-1850	England	33.42	4.64	0.130
Oats	1750-1850	England	38.69	7.70	0.199
Wheat	1884-1939	Great Britain	31.26	2.227	0.071
Barley	1884-1939	Great Britain	33.00	1.786	0.054
Oats	1884-1939	Great Britain	40.14	1.810	0.045
Wheat	1878-1944	Germany	1.886	0.194	0.103
Oats	1878-1944	Germany	1.850	0.205	0.111
Barley	1878-1944	Germany	1.752	0.228	0.130
Wheat	1815-1950	France	1.177	0.167	0.142
Wheat	1871-1950	France	1.317	0.195	0.148
Oats	1871-1950	France	1.273	0.152	0.119
Barley	1871-1950	France	1.198	0.141	0.118
Wheat	1865-1950	Sweden	1.786	0.274	0.153
Oats	1865-1950	Sweden	1.636	0.170	0.104
Barley	1865-1950	Sweden	1.425	0.187	0.131

Note: the standard deviations were estimated using the Hodrick-Prescott filter. Yield data from Campbell, *Three Centuries*; Turner, Beckett, and Afton, *Farm Production* (annual chronologies reconstructed from original data supplied by the authors); Mitchell, *British Historical Statistics*, pp. 90-91; Mitchell, *European Historical Statistics*, pp. 237, 240, 241, 248, 253-54, 265.

Table 4: England/Great Britain, Germany, France, and Sweden, annual variations in grain yields

have been a real reduction in the year-to-year variability of yields. Very likely the magnitude of the difference between these medieval and modern yield variabilities is exaggerated by the differing character of the datasets and their contrasting geographical coverages, since, other things being equal, the greater the geographical scale the smaller the year-to-year variability of yields.[53] Nevertheless, that some real progress had been made is confirmed by coefficients of variation calculated on annual chronologies of yields reconstructed from farm accounts for England between 1750 and 1850, for, compared to 1268-1480, those for wheat and barley are a quarter to a third lower (Table 4). Only yields of oats, whose methods of cultivation had been transformed by the massive growth in demand for fodder, had shown no improvement.[55] Fogel thus overstates his case in claiming that post-medieval technological change greatly improved grain yields but had little impact on their coefficient of variation.[56] These contrasting findings also highlight the different results that can be obtained when the reliability of harvests is measured at the micro-level of individual production units, and then aggregated, or calculated at the macro-level of the country as a whole using national output statistics. Variations which may seem small and manageable at a macro-level can assume entirely different dimensions at the micro-levels of the individual farm,

[53] Barquin, “Elasticity of Demand,” p. 258.

[55] Wrigley, “Advanced Organic Economy,” pp. 445-6, 458-9.

[56] Fogel, “Second Thoughts,” p. 252 fn. 8. Persson (*Grain Markets*, p. 113) also believes that between the sixteenth and nineteenth centuries ‘while yields increased there is to my knowledge no evidence that yield variance changed much.’

household, village, and region, where the difference between sufficiency and scarcity really counted.

V. THE FREQUENCY OF 'BACK-TO-BACK' FAILURES

Yield data offer another perspective on the variability of harvests and frequency of serious subsistence crises and famines in medieval England. Here the notion is exploited that many, if not most historical famines as well as the episodes of most acute dearth have been the product of back-to-back harvest failures.[57] There are three reasons why harvest outcomes might be serially correlated. First, there could be some serial autocorrelation in the weather and/or plant diseases, as in the case of the major climate anomaly responsible for the Great European Famine of 1315-21 and concurrent European cattle panzootic of 1316-21, or the blight-induced Irish potato famine of 1845-51. Second, a poor harvest, indicated by a low yield ratio, might mean thinner sowings and deficient yields the next year (although on the demesne farms represented in the medieval crop-yields database bad harvests had little effect upon seeding rates and any curtailment of production tended to take the form of a reduction in the sown area, so that in the aftermath of a genuinely deficient harvest output rather than yields *per se* were reduced). Third, any reductions in fertilizer and draught power

[57] 'Great' famines which have resulted from such consecutive harvest failures include the 'Great' European Famine of 1315-17, the 'Great' Irish Famine of 1845-50, the 'Great' North China Famine of 1876-78, and the 'Great' Leap Forward famine of 1959-61: Ó Gráda "Making Famine History."

following a bad year, whether because animals were dead or malnourished, or because farmers themselves were suffering, could reduce yield ratios.

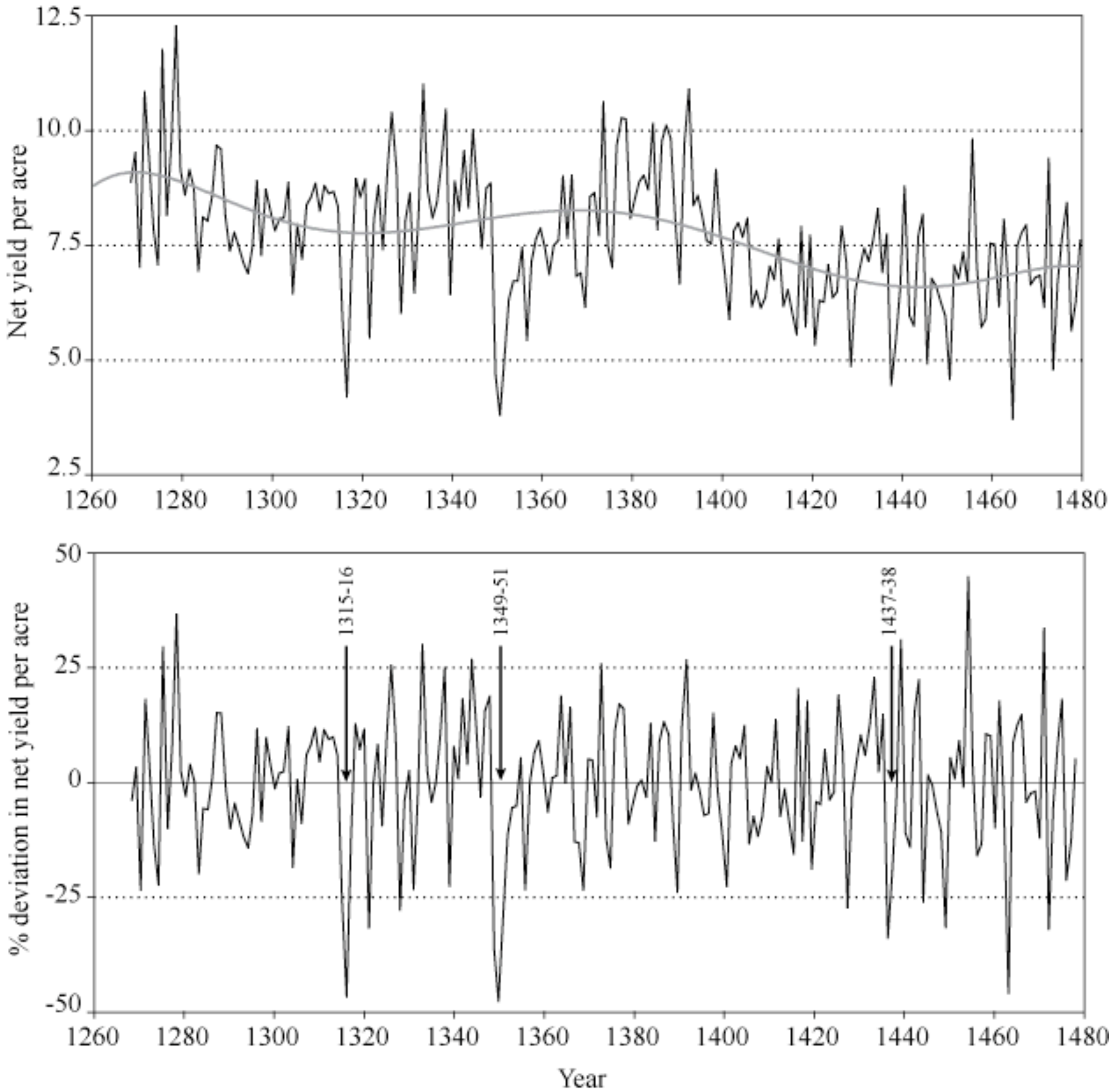
BACK-TO-BACK DEFICITS:	WHEAT	BARLEY	OATS	W-B-O
Prob <90% of trend value	0.085	0.089	0.075	0.066
Average/Expected	1.140	1.088	1.127	1.350
Prob <80% of trend value	0.033	0.042	0.014	0.019
Average/Expected	1.089	1.872	0.945	1.479
Prob <70% of trend value	0.019	0.009	0.005	0.009
Average/Expected	2.360	1.664	0.832	6.656
THREE-IN-A-ROW DEFICITS	WHEAT	BARLEY	OATS	W-B-O
Prob <90% of trend value	0.005	0.014	0.000	0.005
Average/Expected	0.465	1.599	1.636	1.305
Prob <80% of trend value	0.005	0.014	0.000	0.005
Average/Expected	0.896	4.154	0.000	3.282
Prob <70% of trend value	0.005	0.000	0.000	0.005
Average/Expected	6.615	0.000	0.000	88.61

Notes: The W-B-O column is a weighted average of net cereal yields, using the ratio 2:1:1. 'Average/Expected' is the ratio of actual to predicted frequency. The predicted frequency is set at the once-off probability of such a shortfall squared or cubed. Yield data from Campbell, *Three Centuries*.

Table 5: Likelihood of 'back-to-back' harvest failures, England 1268-1480.

Table 5 is derived from fitting the medieval wheat, barley, and oats yield data to a Hodrick-Prescott filter and identifying those years with gross and net yields 10, 20, and 30 per cent below trend. Focusing on net yields, between 1268 and 1480 back-to-back shortfalls of over 10 per cent for individual cereals were not unusual, and were somewhat more common than might be expected on the basis of squaring once-off probabilities. For example, the statistical probability of a back-to-back shortfall in net wheat yield of 10 per cent or more was one in twelve (0.085), but such shortfalls occurred 14 per cent more often than 'expected'. Note how the likelihood of a serious shortfall was less for oats, the buffer crop of the poor, than the other two cereals. Unsurprisingly, the chance of all three major cereals simultaneously doing badly was lowest of all: the probability of a 10 per cent back-to-back shortfall in the net W-B-O yield was one in fifteen (0.066). A failure on such a scale across all crops would almost certainly have led to genuine hardship and malnutrition for many, though hardly classic famine conditions. Back-to-back shortfalls sufficient to result in major famines were much rarer, especially those affecting all three major grains. For wheat and barley consecutive net reductions of a fifth or more were liable to occur only about once every three or four decades, although in this period they also occurred somewhat more often than might be expected if they were purely random. The most dangerous shortfalls of all were double back-to-back (i.e. three-in-a-row) failures of this magnitude but they were 'out-of-the-blue' events likely to occur once in every two or three centuries.[58] Evidence on their randomness is mixed; they were more frequent in the case of wheat (gross yield), barley (net yield) and W-B-O (net yield), but not otherwise (Table 5).

[58] Only in the case of net barley yields are any of the entries in the bottom half of Table 4 greater than 0.005.

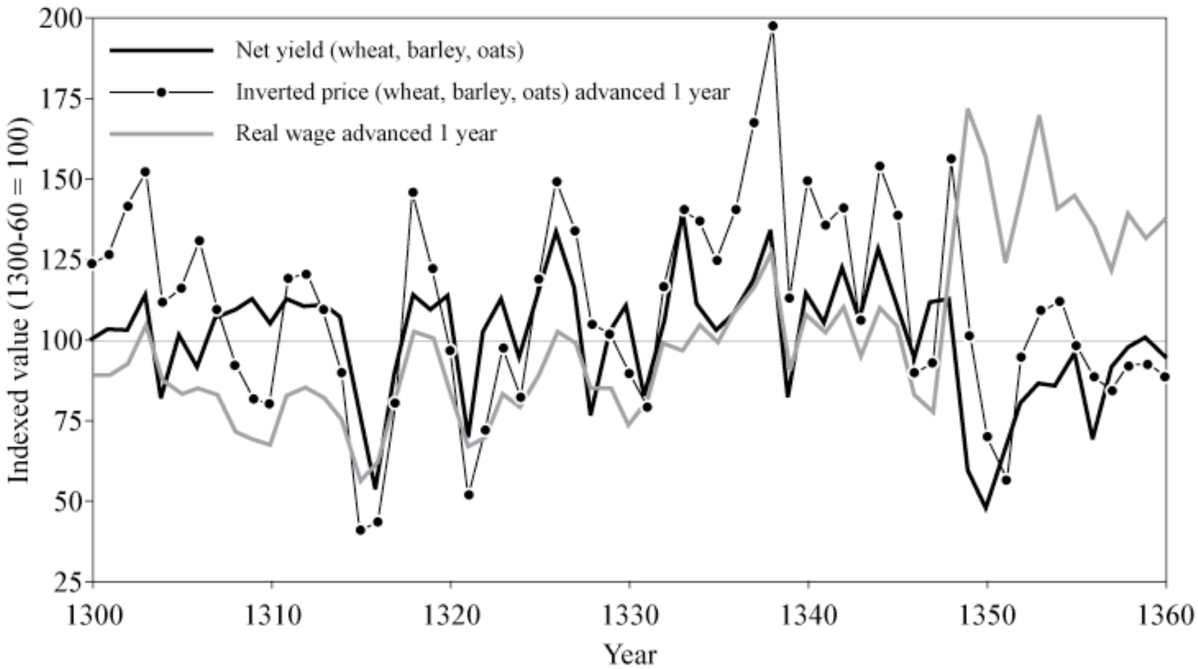


Note: yield data from Campbell, *Three Centuries.* W-B-O = (W x 0.5) + (B x 0.25) + (O x 0.25)

Figures 4A and 4B: England 1268-1480, deviations from trend in net wheat-barley-oats (W-B-O) yields.

Across the entire period, 1268-1480, three episodes registered back-to-back reductions in the net W-B-O yield in excess of 25 per cent: 1315-16, 1349-51 (the only three-in-a-row failure of this magnitude), and 1437-8 (Figure 4). In 1315 and 1316 the yield reductions exceeded 25 and 47 per cent, respectively, and they exceeded 30 per cent in 1349, 1350, and 1351, and also in 1437. The greatest yield reductions of all occurred in 1316 (47 per cent), 1350 (47 per cent), and 1464 (46 per cent) and 1349-51 (over 30 per cent in all three years) and provide a yardstick against which all other serious harvest shortfalls can be measured.[60] This was as bad as it could get. Together, 1315 and 1316 thus stand out as having witnessed the sharpest yield reduction during the period under review, with winter-sown wheat and rye exceptionally hard hit, and 1349-51 the most prolonged, when, although wheat again fared worst, deficient crops of barley and oats greatly exacerbated the crisis. Indeed, yields of barley and oats failed disastrously in 1352, thereby extending the harvest crisis into an unprecedented fourth year. This again highlights the importance of taking all three major grains into account when judging the scale and duration of harvest shortfalls. Other things being equal, of course, the disastrous three/four-year failure of 1349-51/52 should have presented producers and consumers with a greater challenge of survival than the marginally more extreme two-year failure of 1315-16. That, paradoxically, this was not the case is brought out by the movement of prices and wages.

[60] In 1464 the wheat crop was just below trend, but the oats and barley crops were extremely poor.



Note: yield data from Campbell, *Three Centuries*; price data from URL: http://www.iisg.nl/hpw/data.php; wage data from Clark, "Long March of History," pp. 132-3. The yields and prices are combined using the formula: (wheat x 0.5) + (barley x 0.25) + (oats x 0.25). The prices and wages are advanced 1 year so that they synchronize with the yields. Prices are inverted because the normal response to a reduction in yield was a rise in price.

Figure 5: English harvests, grain prices, and farm workers' real wages during the crises of 1315-17 and 1349-51.

Figure 5 plots the combined net yield per seed of wheat, barley and oats, a combined price for these same three grains (inverted and advanced 1 year to bring out the coincidental movement between yields and prices), and Clark's real farm-workers' wage rates (also advanced 1 year). In a period notable for the variability of its yields (Figure 3) the pronounced back-to-back supply-side shocks of 1315-16 and 1349-51 stand out clearly. Moreover, not only was the latter the more prolonged event, but recovery from it was slower since it was not until the late 1370s that yields recovered to the levels recorded on the eve of the crisis. Nevertheless, the price response to the crisis of 1349-51 was altogether slower and slighter than that of 1315-16, which witnessed the greatest inflation of grain prices during the entire Middle Ages and arguably the greatest on English historical record.[61] During the earlier of these two crises the scarce grain, reduced agricultural employment, and sky-high food prices had squeezed the entitlements of wage earners hard, and the real wage rates of English farm workers sank to their lowest recorded point ever.[62] That this had tragic consequences for many of those dependent upon their wages for their livelihoods is implied by the fact that in the wake of the crisis nominal wages registered a modest rise, probably because famine mortality had thinned the ranks of laborers. As well as the accounts of contemporaries, who were in no doubt that England and much of northern Europe were in the grip of dire famine, all the classic economic symptoms of famine may be observed during these grim years: rural credit arrangements collapsed triggering a wave of petty land sales, many also traded parcels of land for food; those who had exhausted or forfeited their legal entitlements to food resorted to theft and crimes against property soared; rural to urban migration increased in a

[61] Campbell, "Nature as Historical Protagonist."

[62] 1316 is the lowest point on Clark's 1209-1869 index of farm-workers' real wage rates ("Long March of History," pp. 130-4), whereas 1597 — another year of extreme scarcity — is the lowest point on the Phelps Brown and Hopkins 1264-1954 index of building workers' real wage rates (*Wages and Prices*, pp. 28-31).

desperate quest for food and alms; marriages were postponed for want of the means to establish new households; and there are clear signs that death rates rose.[63]

That the consecutive harvest failures of 1315 and 1316 resulted in a genuine famine with great economic hardship and significant excess mortality cannot be in doubt. Why, then, did the three-in-a-row failure of 1349-51, so much greater in its cumulative incidence, not produce a subsistence crisis of similar or superior magnitude? The vital difference between the massive supply-side shocks of 1315-16 and 1349-51/52 is that the latter coincided with an even greater demand-side shock in the form of the Black Death. In fact, the massive mortality of workers and managers alike — usually reckoned to have been between 30 and 45 per cent — is likely to have compounded the harvest failure and may well explain why the cheaper spring grains of barley and oats together with peas and other legumes fared particularly badly, since priority was given to harvesting and threshing the more highly valued wheat.[64] Had this been an ordinary harvest failure — as in 1315-16 and again in 1437-8 — the real wage rates of farm workers should have collapsed, while nominal wage rates should subsequently have displayed some small upward adjustment as famine deaths reduced the supply of workers.

[63] Jordan, *Great Famine*; Campbell, "Nature as Historical Protagonist."

[64] Chronicler Henry Knighton noted that 'many crops rotted in the fields for want of harvesting…there was such an abundance of grain that almost no one cared for it' (*Knighton's Chronicle*, p. 101), although this description probably relates more to the situation on peasant holdings than on demesnes.

Instead, as Figure 5 demonstrates, in 1349 real wage rates rose dramatically and, paradoxically, remained high in 1350 notwithstanding a second consecutive bad harvest.[65] For the real wage rates of the most marginal economic group to have registered such striking gains in the midst of one of the worst back-to-back harvest failures on record highlights the unique nature of this, the greatest (in relative terms) of all major historical mortality crises. Famine on this occasion had been forestalled by plague and the windfall economic gains bestowed upon those who survived the pandemic and its repeated visitations meant that it would be a long time before England's population would again be so vulnerable to harvest failure. This is a reminder that poor yields did not always result in price inflation or famines since much hinged upon the economic and demographic context within which the harvest failure occurred.

The Black Death is probably the single greatest historical example of a massive biological disaster eclipsing a major food availability decline, but it is not unique.[66] Later centuries afford several examples of mortality crises which began

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[65] Clark's farm workers' wage series is used since it captures best the improved circumstances of workers lucky enough to have survived. Labor's gain relative to land is captured in Henry Knighton's lament that 'ox hides fell to a wretched price, namely 12d., and yet a pair of gloves would cost 10d., 12d., or 14d., and a pair of breeches 3s. or 4s.' (*Knighton's Chronicle*, pp. 103, 105) Clark demonstrates that Edward III's efforts at regulating wages through the Ordinance of Labourers (1349) and the Statute of Labourers (1351) had only limited effect ("Long March of History," pp. 115-17). Penn and Dyer ("Wages and Earnings," p. 359) state that those laws were 'broken in each year by hundreds of thousands of workers'.

[66] Another example, familiar to readers of Alessandro Manzoni's 1827 — revised 1842 — novel, *The Bethrothed (I Promessi Sposi)*, is the plague that followed famine in northern Italy in 1629-30.

as subsistence crises but then became transformed by epidemic disease into crises of an entirely different nature and order. The mortality crises of 1556-9 and 1727-30 both fall into this category when, respectively, influenza and smallpox (in combination with other diseases) drove death rates to levels that famine alone could not have achieved. Neither of the latter, however, involved a population whose purchasing power and living standards were as abjectly low as that struck by the double catastrophe of plague and harvest failure in the 1340s. Without the Black Death the harvest failure of 1349-51/52 would undoubtedly have precipitated another major famine, possibly worse even than that of 1315-16, if only because such a large proportion of the population remained so poor and vulnerable to calamity and economic recovery from that earlier famine and its accompanying cattle panzootic remained incomplete.[67] Likewise, it was because the major back-to-back harvest failure of 1437-8 occurred at a time when population levels were low and living standards exceptionally high by pre-industrial standards that its demographic and economic repercussions remained comparatively modest. The consequent rise in nominal wages may point to a mortality-induced reduction in labor supply but given the greater affluence of the population the scale of the economic crisis can hardly have matched that of 1315-16.

Whereas the catalysts of the greatest historical food availability declines may have lain for the most part within the natural world, their impacts and consequences patently owed a great deal to prevailing socio-economic conditions.

[67] Campbell, "Physical Shocks."

For this reason subsistence crises and famines tended to cluster in periods when society at large was particularly vulnerable to scarcity, as in the first halves of both the fourteenth and seventeenth centuries. Periods of greater prosperity were not immune to famine — witness the 1430s and 1740s — if the environmentally induced food availability decline was great enough, but these famines rarely matched in hardship those of the periods of greatest economic austerity.

VI. CONCLUSIONS AND IMPLICATIONS

Newly available yield data endorse Persson's view that in England, as in most of Europe, until at least the end of the Middle Ages, and probably for far longer, major food availability declines underpinned many if not necessarily all episodes of pronounced grain-price inflation. Pre-industrial European price elasticities of grain were *not* low and are likely to have been significantly higher in the medieval and early modern periods than in the late nineteenth century when official agricultural statistics first become available. Indeed, national statistics undoubtedly understate the magnitude of the local and regional variations in output which brought so much hardship to pre-modern populations. On the evidence of micro-level data, between 1268 and 1480 net grain-yield reductions in excess of one-fifth were not unusual and in the worst harvests of all mean reductions of more than two-fifths are recorded, while even greater reductions for individual crops were not unknown. The most dangerous food availability declines, however, were those which resulted from back-to-back harvest failures of all the major crops, and these were far less frequent, occurring perhaps once a generation or less. Harvest failures on the scale of 1315-17 or 1349-51 were once in 200-year events, hence the occurrence of two such harvest disasters within the narrow space of a single generation prompts speculation as to whether there was an element of autocorrelation in the precipitating environmental causes.[68]

That prices are an inadequate surrogate for direct evidence of harvests is confirmed. As the triple harvest failure of 1349-51 demonstrates, not all major food availability declines triggered inflationary price spikes and, conversely, not all inflationary prices spikes resulted from food availability declines. At this early stage of economic and agrarian development and state formation, with its imperfect markets and selective and voluntary welfare provision, recurrent harvest shortfalls were an inescapable fact of life which delivered profits to the prosperous and hardship, malnutrition, and even death to the needy. Five centuries later, thanks to the efforts of English farmers, grain harvests were both substantially heavier and significantly less variable. Across Europe there is evidence that from the sixteenth century improved integration of grain markets was dampening down the scale of year-to-year price variations so that in England the magnitude of grain price variations during the 'cold' seventeenth century was significantly less than during the 'unstable' fourteenth century. Following the run of bad harvests in the 1590s, a nation-wide system of public poor relief was put in place which better protected the food entitlements of the most vulnerable in hard times and governments became

[68] Campbell, "Physical shocks."

more pro-active in attempting to guarantee the nation's grain supply and maintain public order in hard times. The last harvest failure to elevate deaths above births occurred in the 1740s, precipitated by some of the most extreme and abnormal environmental conditions of the second millennium A.D. Nevertheless, the greater resilience of English society ensured that the crisis was on a smaller scale than in those other European countries still vulnerable to such extreme shocks. Thereafter, serious harvest shortfalls ceased to present a serious economic and demographic threat and became more a source of public disorder than of excess mortality, assuming an importance to the civil authorities which they had never possessed in the Middle Ages.[69]

Whereas England was haunted by famine in the Middle Ages, it had already largely banished that specter by the time it embarked upon its industrial revolution and Malthus wrote his *Essay*. This was a signal achievement and contributed materially to the well being of the humblest members of society. It owed little to any exogenous change in the incidence or magnitude of the environmental hazards with which agricultural producers in all periods had to contend and a very great deal to the improved capacity of governments, markets, welfare institutions and society at large to cope with those hazards and the harvest shortfalls which they continued to deliver.

[69] Randall and Charlesworth, *Moral Economy*; Randall, *Riotous Assemblies*.

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