POPULATION AND LIVING STANDARDS IN ENGLAND DURING 'THE LITTLE ICE AGE' [1]

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[1] This paper borrows freely from Kelly & Ó Gráda (2010a, 2010b, 2010c), Campbell & Ó Gráda (2010), and from an ongoing collaboration with Morgan Kelly and Joel Mokyr. The comments of Ann Carlos and Kevin O'Rourke on a first draft are gratefully acknowledged.

POPULATION AND LIVING STANDARDS IN ENGLAND

2007-2010 have been banner years for the publication of new monographs on the European economy before the Industrial Revolution. Works by economic historians Gregory Clark (2007), Jan de Vries (2008), Jan Luiten van Zanden (2009), Bob Allen (2009), Joel Mokyr (2010), and Gunnar Persson (2010) have greatly enriched the debate about the origins of modern economic growth. All are written with a multidisciplinary readership in mind. Informed by economic theory, they are also history-rich, employing new data on aspects ranging from book publishing to human heights, and from patents to leisure. They are also based on sophisticated understandings of the constraints imposed by technology, and of the institutional and cultural contexts involved.

These interpretations of the origins of economic growth will undoubtedly prompt neo-malthusian and post-malthusian growth theorists to further revise and sharpen their models. This paper's modest contribution to the debate is empirical. It offers some new 'facts' on the English economy before the Industrial Revolution and raises some questions about received 'facts'.

1. 'MALTHUSIAN' CHECKS:

How common were serious harvest shortfalls in Europe in the past? How often did they lead to subsistence crises or outright famine? One of the important implications of Wrigley and Schofield's classic reconstruction of English population is that England's demographic regime was 'low pressure' in the pre-industrial era, in the sense that the short-run response to food price or real wage shocks was modest. This echoes Malthus's own belief that Europe had long been less subject to the 'ultimate check' of death from famine than the rest of the globe, and that while untold millions of European lives had been blighted by malnutrition, 'perhaps in some states an absolute famine may never have been known' (Malthus 1826: II, ch 13). Robert Fogel (2004) similarly doubts the historical importance of famine. While emphasizing the significance of hunger, he believes that scarcities arose more from distributional inefficiencies than from genuine food availability declines. Less sanguine and more critical assessments of the resilience of European agriculture to exogenous environmental shocks in the pre-industrial era have been offered by Karl-Gunnar Persson (1999: 47-64) and Rafael Barquin (2005).

One must beware of overgeneralization. Demographic data for medieval England are scarce and hard to interpret, but they seem to offer evidence of a demographic regime quite different to that of later centuries. Estimates of mortality in medieval southern and central England have been derived from manorial data. M. M. Postan and Jan Titow (1959) inferred a death rate ranging from 40 to 52 per thousand for adult property-holders from heriot data, while Zvi Razi's estimates (1980) suggesting an adult life span of 'between 18 and 22.8 years' were based on court rolls. The resulting implied life expectancies are implausibly low. More convincing recent evidence suggests that landless males or monks who had managed to survive to age 20 in medieval or late medieval southern England might have expected to live another 27 years or so. However, even these numbers are still appallingly low (Ecclestone 1999: 24; Hatcher *et al*. 2006; Wrigley et al. 1997: 290-91).

Ongoing research by Morgan Kelly and myself (Kelly & Ó Gráda 2010a) confirms the vulnerability of medieval Englishmen and Englishwomen to harvest shortfalls. Following Ronald Lee (1981) and others we measure the short-run response of mortality to adverse price and wage shocks. Continuous data on deaths are lacking, so we rely on proxies stemming from the feudal system. Here I describe one proxy consisting of over twelve thousand entry fines paid by tenants on the Winchester estates in southern England in order to inherit land between the 1260s and the Black Death in 1349.[2] By counting the annual number of these transfers listed as inheritances, we can see how strongly deaths responded to harvest yields and earlier mortality. The number of inheritances shows two spikes where we would expect them: in 1317 at the peak of the Great Famine, and in 1349, the first year of the Black Death.

The social status of those who died may be inferred from the size of the entry fine their heirs paid. To be a middling farmer required about a half-virgate (roughly 20 acres usually) of land, which commanded in the early fourteenth century an entry fine of at least 30 to 40 shillings, and often considerably more. This corresponds to the largest 10 to 15 per cent of fines in our sample, the median fine in our post-1302 sample being 7.5 shillings. Typical estimates for the early fourteenth century are that about half of all tenants owned less than a quarter virgate, the bare minimum for subsistence (Titow

[2] These data were compiled by Mark Page (2006).

1969: 78–81). In other words, then, most of the tenants in our sample of fines are semi-proletarian smallholders with too little land to support themselves. Manors varied considerably in size and continuity of records. For the period before 1349, the ten largest manors accounted for fifty per cent of deaths, and the largest twenty for seventy per cent, and these large manors have almost continuous records. By contrast, records for the smallest manors are extremely fragmentary.

Annual fluctuations in fines were highly sensitive to cereal prices and real wages. Table 1 reports the results of a regression of number of inheritances on each manor on the real wages and inheritances on the same manor in the two previous years; both for the twenty largest manors and the entire sample. Dummies are added for years of unusual mortality: 1269, 1317, 1318 and 1342–44. Mortality responds strongly to real wages in the previous year, with an elasticity exceeding one half. Note too that increased mortality in one year is followed by slightly higher mortality in the two following years. This slight positive autocorrelation is in contrast to the strong negative autocorrelation in mortality after the sixteenth century. The size distribution of fines allows us also to see if years of severe epidemic mortality—1317 and 1349— had different social distributions of mortality than ordinary years. After 1303, the median fine is 80 pence, identical to the median fines in 1317 and 1349, suggesting that tenants at all levels suffered equally during these crises.[3]

[3] This assumes, however, that fines were ‘sticky’ in bad years.

[Table 1 about here]

The English nobility were legally tenants of the king which meant that when a noble died without adult children, their estates reverted to the crown. To determine the value of the property and the existence of possible heirs, an *Inquisitio Post Mortem* (IPM) was carried out, usually by neighbouring nobles. The records of all surviving *IPMs* from 1300 to the Black Death were used by Campbell (2005) to assess the income of the English nobility, and these data can be used as a proxy for annual male deaths among that class. An analysis of the relationship between real wages in one year and *IPMs* in the next produces similar results to those reported in Table 1, implying that wealth was no shield against death from epidemic disease that had incubated among hungry peasants: the elasticity of mortality with respect to the real wage of agricultural labourers was almost as high as in Table 1 (Kelly & Ó Gráda 2010a). In the medieval era we find that falls in real wages caused by poor wheat harvests were deadly at all levels of society.

Newly available micro-level crop yield data endorse the view that in England, as in most of Europe, at least until at 1500AD, and probably for far longer, major food availability declines underpinned many if not necessarily all episodes of pronounced grain-price inflation. Combining price and crop yield data implies—contrary to Fogel's claim in the *Escape from Hunger* (2004)—that pre-industrial European price elasticities of demand for 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 (Campbell and Ó Gráda 2010).

Between the mid-13th and late-15th centuries crop shortfalls of more than one-fifth were not unusual and in the worst harvests of all shortfalls of more than two-fifths are recorded. The most dangerous situations, 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 (compare Ó Gráda 2007). 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.

[Table 2 about here]

2. MEDIEVAL TO EARLY MODERN

The belief that there was no sustained improvement in living standards before the Industrial Revolution informs modern unified growth theory. In Oded Galor's words, the pre-industrial world was 'in a low level equilibrium in terms of income per capita… The growth of total output resulting from technological progress [was] matched by population growth so that per capita income fluctuate[d] around a low stable level, with no significant progress in average living standards over a long period of time.' Or, to quote Robert Lucas (1996), 'Three hundred years ago, living standards in all economies in the world were more or less equal to one another and more or less constant over time'. Clark in *Farewell to Alms* claims likewise.

Recently-constructed time series by Allen and Clark describe a dramatic fall in real wages in England between the late fifteenth and the early seventeenth centuries, with stasis or mild recovery thereafter. Figure 1 summarizes Clark's findings: fluctuations but no sustained increase before the Industrial Revolution.

How does this square with the shift from the harsh medieval demographic regime just described to one in the seventeenth century showing but the faintest evidence of a link between low wages and high mortality (Nicolini 2007; Kelly and Ó Gráda 2010a)? Did living standards really fail to rise? Surely the shift in demographic regimes suggests that something must have changed between the Middle Ages and the two centuries of so before the Industrial Revolution? In what follows I present some evidence in favour of a rise in living standards over this period which fits with the described above.

[Figure 1 about here]

2.1. *Life expectancy*

Above I reported estimates of *e(20)* of about 27 years for medieval England. In the seventeenth century, however, Englishmen and Englishwomen who survived to age 25 had on average another 31 years to live; in the eighteenth century, another 34 years.[4] Such increases in life expectancy can only have added to the 'true' standard of living. In the model first proposed by Dan Usher (1973) and applied by Jeffrey Williamson to England during the Industrial Revolution (Williamson 1984: 158-60; compare Becker, Philipson, & Soares 2005), the rise in the 'true' standard of living would depend on the proportionate increase in life expectancy and the assumed elasticity of annual utility to annual consumption. For example, assuming an elasticity of 0.5 and an increase in *e(0)* of one-tenth[5] would have meant a gain of one-fifth in 'true' living standards. Moreover, increasing life expectancy is not just a component of the current standard of living; it also prompts increases in future living standards.[6]

Demographic regimes in England and France also diverged, with death rates in pre-revolutionary France much higher on average. In the first half of the eighteenth century *e(0)* in England was about 35-37 years; in mid-eighteenth century France *e(0)* was about 25 years. French mortality also

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[4] In Malthusian equilibrium such increases would have required either a reduction in the subsistence wage or a compensating movement in how births responded to wages.

[5] Since gains to the life expectancy of young adults would not affect the significant proportion dead before age 20 or 25.

[6] See e.g. Aghion *et al*. 2009.

varied more, although fluctuations in both counties show signs of attenuation over time. Between 1670 and 1720 France was subject to three major crises while England was virtually immune; thereafter vital rates fluctuated less in both countries, with the important exceptions of 1727-30 and, to a lesser extent, 1740-42 in England.

2.2 *GDP and Wages*

According to Clark (2009: 1160), Angus Maddison's widely-used historical GDP data 'have an imprimatur that is completely out of line with their dubious provenance'. Be that as it may, the more careful, if still tentative, estimates of Apostolides *et al*. (2009a) deserve serious consideration, and they tell a story very different to that told by real wage series (Figure 2). They imply that between 1450 and 1700 GDP per head rose by one-sixth; over the same period, Clark's real wages dropped by half.[7]

This is a reminder of a dimension marginalized in Clark's account: the distribution of income. Granting, just for the sake of argument, the claim that medieval English agricultural labourers were no better off than foragers and cavemen, the comparison overlooks the likely reduction in the share of such unskilled labourers in total employment after the Middle Ages. By Gregory King's reckoning cottagers, paupers, labourers, and servants together

[7] It also bears noting that several of the studies of GDP per head elsewhere in Europe in this period presented at the IEHA Utrecht meetings in August 2009 record mild increases or, at worst, modest declines. These papers are still available online at: *http://www.wehc2009.org/programme.asp*.

represented only one-third of the population in 1688 and received only one-ninth of income (Table 3). The remaining two-thirds received an average of over four times as much.

[Table 3 and Figure 2 about here]

2.3. *Output and Price Variability*

Campbell and Ó Gráda (2010) argue that grain harvests in England were both substantially heavier and significantly less variable in the eighteenth century than in the fourteenth or fifteenth. Table 4 compares the coefficients of variation calculated on de-trended annual chronologies of *gross* yields of wheat, barley, and oats for the periods 1268-1480 and 1750-1850. The coefficients of variation for wheat and barley are a quarter to a third lower by 1750-1850: only the variability of oats yields showed no improvement.

Precisely how this was achieved remains to be established but a likely explanation is the biological innovation of selecting and sowing sounder seed. The range of solutions to crop damage caused by rain, fungi, weeds, and pests proposed in print grew from the sixteenth century onwards, and while evidence for a specialist seed trade is lacking for medieval England, there is increasing evidence for it from the seventeenth century onwards. None of this proves the efficacy of specific 'remedies' but points to the ubiquity of processes of experimentation, adaptation, and learning-by-doing that sought to minimize the risk of poor harvests, and so improve the standard of living (Thick 1990;

Turner *et al*. 2001: 78-81; Allen 1992: 206-7; Buttress & Dennis 1947; compare Olmstead and Rhode 2002).

[Table 4 about here]

This apparent reduction in year-to-year yield variability calls for several comments. First, the claim for a reduction is not entirely new (compare Neveux & Tits-Dieuaide 1979), but the direct evidence previously advanced has been hardly convincing. Second, any reduction on the scale indicated above must have entailed a significant decline in the vulnerability to harvest shocks. A decline in the coefficient of variation of wheat yields from 0.205 to 0.123 (as above) would have meant a reduction from roughly 15 per cent to 5 per cent in the probability of yields less than four-fifths the average in any year. Reduced variability is another likely reason why famines in England became less common. Indeed, some of the reduction in price fluctuations noted earlier may have been to agricultural progress rather than market integration. Third, the case for reduced variability is, of course, only as strong as the underlying data, and little can be said about the chronology of any reduction. Fourth, it may be incorrect to claim that post-medieval technological change greatly improved grain yields but had little impact on their coefficient of variation. In fact, comparison with a corresponding set of coefficients calculated using national output statistics for the period 1884-1939 (see Table 4) implies that yield variability declined further during the nineteenth century.

In the past several scholars (e.g. Persson 1999; Rönnbäck 2009) have highlighted the role of increasing market integration in the early modern era (compare Figures 3 and 4). In similar vein McCloskey and Nash (1984) have pointed to the reduction in the cost of storage and increased intertemporal arbitrage due to reduced interest rates. Without wanting to dismiss such improvements, I would also include the role of reduced crop yield variability in reducing price fluctuations.

In sum, the vulnerability to famine that characterized the Middle Ages had been already largely banished by the time Malthus wrote his *Essay*. This signal achievement contributed materially to the wellbeing of the humblest members of society. It probably owed little to any exogenous change in environmental hazards (on which more below) and a lot to the improved capacity of governments, farmers, markets, and society at large to cope with shocks.

[Figures 3 and 4 about here]

2.4. *Welfare*

Morgan Kelly and I (2010c) argue that the nation-wide system of public poor relief put in place in England in the late sixteenth century—known as the Old Poor Law—better protected the food entitlements of the most vulnerable in hard times, and thereby limited both life-cycle and harvest-induced destitution. The poor law squared a concern for economy with effective relief. The system had its limits; it could not prevent excess mortality from famine in the late 1720s and early 1740s. However, those crises were minor relative to earlier. We argue that the institutional form of the Old Poor Law owed as much to English history as it did to increasing income. Nonetheless, elites had a long-standing interest in limiting the spread of infectious disease and the anti-social behaviour that accompanied subsistence crises, and the rise in GDP per head after 1500 enabled them to act.

2.5. *Further considerations*

De Vries (2008) highlights the role of increasing variety and colonial goods in the 'industrious revolution'. Jonathan Hersh & Hans-Joachim Voth (2009) go further, calculating the welfare gain to Britain of three 'new goods', tea, coffee, and sugar. Employing various measures of this gain, the simplest of which is that proposed by Hausman (1999), they reckon the welfare gain from their 'new goods' at about one-sixth of consumer expenditure by the eighteenth century.

The urbanization ratio is an imperfect measure of the share of the labour force in non-agricultural occupations (Persson 1992). Nonetheless, the huge rise in the proportion of city- and town-dwellers in England from 1500 on (see Figure 5, based on de Vries 1984: 39) implies productivity growth in agriculture, particularly since England was a food-exporting economy at the end of the period. Again, an increase in average living standards is indicated, although this must be weighed against the demographic penalty associated with urbanization (Wrigley 1985).

Finally, there was also a huge increase in literacy over the same period. In England the proportion of grooms who could sign the marriage register—a commonly accepted measure of literacy—rose from only 6 percent in 1500 to over three-fifths in 1750, and was already significant by 1650 (Allen 2009: 12; Houston 1982). The increased ability to afford the investment in schooling and acquiring literacy also points to rising living standards. The link in cross-section in a later era between literacy, on the one hand, and measures of health and well-being such as housing quality and mean adult height, on the other, certainly point in that direction.

[Figure 5 about here]

In sum, a range of considerations rejects the impression of no sustained improvement in living standards before the Industrial Revolution. This suggests that while real wage series may usefully reflect the lot of those at the very bottom of the socio-economic ladder, they are a fallible indicator of long-run trends in living standards more broadly defined.

3. *WEATHER MATTERED, CLIMATE DIDN'T*

Our context so far has been a Malthusian world in which demographic adjustment eventually whittles away any rises—or falls—in real incomes. But living standards could also have been held back by non-Malthusian forces. Several non-Malthusian scholars have linked economic hardship in the medieval and early modern eras to climate change (e.g. Campbell 2010; Steckel 2004). Meteorologist Hubert Lamb, the first to draw the link between a Little Ice Age and broader economic and social trends, has drawn attention to the alleged 'parallelism of climatic and cultural curves' (1995: 318) as the Little Ice Age drew to a close. Richard Steckel has blamed the Little Ice Age for a cooling trend that 'wreaked havoc' on northern Europe for half a millennium, while Brian Fagan has recently described it as a defining period that 'changed the course of European history... changed European agriculture, helped tip the balance of political power from the Mediterranean states to the north, and contributed to the social unrest that culminated in the French Revolution'. Against such claims, Emmanuel Le Roy Ladurie and others have argued that the economic and (by implication) political impact of the Little Ice Age was insignificant (Lamb 1995: 318; Steckel 2004; Fagan 2000; Le Roy Ladurie 1971).

A combination of resonant images has linked the Little Ice Age firmly to Northern and Western Europe. These images include the collapse of Greenland's Viking colony and the demise of grape-growing in southern England in the late medieval era; the Dutch winter landscape paintings of Bruegel the Elder (1525-69) and Avercamp (1585-1634); the periodic 'ice fairs' on London's

Thames, ending in 1814; and, as the Little Ice Age waned, the contraction of Europe's Nordic and Alpine glaciers.

How much did this alleged cooling matter? On thing is evident: in medieval Europe crop yields were very sensitive to weather. Combining Campbell's crop yield data with meteorological data described in more detail below, Morgan Kelly and I (2010) find that a one degree rise in summer temperature (equivalent to a change of 1.5 standard deviations) increased average wheat yields by 5 per cent, while a one standard deviation increase in the thickness of oak rings (a weather proxy, on which more below) is associated with a fall of 5.6 per cent in average output. Other crops were less sensitive to weather, and in the expected order. Rye produces coefficients of 0.05 and −0.03 for temperature and tree rings; barley appears unaffected by summer temperature, and has a coefficient of only −0.01 for tree rings; and oats show no measurable effect of weather at all (Table 5). I terms of weather risk, oats offered the best insurance, and had the added advantages of growing on poorer soil than other grain, and producing more calories per acre. Consequently, while weather strongly affected wheat yields, it does not appear to have had a large impact on the spring grains, such as oats, on which ordinary people relied. Oats offered the best insurance against bad weather, besides having the added advantages of growing on poorer soil than other grain, and producing more calories per acre.

[Table 5 about here]

These estimates convey a sense of the damage a significant cooling in temperatures might have inflicted on agriculture in early modern Europe. Assuming linearity, a reduction of two degrees in summer temperatures—significant even by twentieth-first century standards—would have cut wheat yields by one-tenth.[8]

Originally applied in 1939 to an era spanning several millennia in California's Sierra Nevada, the term 'Little Ice Age' now usually refers instead to a global climatic shift towards colder weather occurring during the second millennium. Considerable imprecision about the chronology, geography, and impact of the Little Ice Age remains, however. The chronology of the preceding Medieval Warm Period, identified by Lamb in 1965, is equally elastic. Consensus has also been lacking on the Little Ice Age's geographical reach. The Intergovernmental Panel on Climate Change's *Third Assessment Report* emphasizes the variations in climate change across regions and the possible independence of such variations, so much so that it deems the term 'Little Ice Age' a misleading guide to *global* temperature changes in the past. True, in the Northern Hemisphere the 1500-1900 period stands out, although temperature change even then appears to have been modest relative to that experienced in the twentieth. More recent assessments of the Medieval Warm

[8] However, to the extent that agents would have adapted to the challenge by altering crop mixes, this is an upper-bound estimate of the likely cost.

Period also reckon it to have been only moderately milder than the cooling period that followed.

The ambiguities arise in part from the lack of direct measurements of temperature before the introduction of reliable thermometers in the mid-seventeenth century. Lacking long-run time series data, early accounts of the Little Ice Age (such as Lamb 1965) relied on impressionistic and anecdotal evidence. Uncertainty is compounded by the somewhat conflicting patterns revealed by the now numerous proxy measures of climate change.

Geologist François Matthes (1939) linked his original 'Little Ice Age' to the growth of Sierra Nevadan glaciers following a mid-Holocene thermal maximum, and this prompted others to reconstruct historical glacier lengths (e.g. D'Orefice *et al*. 2000; Oerlemans 2001). Glacial retreat since the late nineteenth century has become one of the hallmark images of global warming. Tree rings offer a second measure of secular climate change: warm and wet weather are associated with faster growth and wider rings (Baillie 1999). Le Roy Ladurie was the first to propose changes in the timing of the grape harvest as a measure of long-run climate change. His analysis of the starting dates of pinot noir harvests in Burgundy, as updated by Isabelle Chuine and her co-authors, reports April—August temperature anomalies with reference to the 1960-1989 period for the city of Dijon (Le Roy Ladurie 1971; Chuine *et al*. 2004).

Time series derived from Northern Hemisphere ice cores—ice cylinders drilled out of polar ice sheets and mountain glaciers—offer another measure of long-term climate change. Yet another valuable source is winter and summer temperature series for the Low Countries that rely on documentary data ranging from letters and diaries to toll accounts to produce weather indices rated on a scale from 1 (=extremely cold) to 9 (=extremely hot). The series yield only scattered data before 1300, but are continuous, or almost so, thereafter (van Engelen *et al*. 2001). The reconstructions present their own different stories. For example, the most northerly ice cores imply much more volatile weather than more southerly ice cores and other reconstructions.

[Table 6 and Figure 6 about here]

Table 6 reports the results of first order autoregressions for each weather series until 1900, and it can be seen that there is little autocorrelation in most cases. Ljung-Box statistics show that annual data are random for English summer and winter temperature and rainfall, and Dutch winter temperature. The apparent temporal dependence in Dutch summer temperature estimates is generated by estimates prior to 1400: when these are omitted the Ljung-Box test indicates randomness. Similarly for the French temperature estimates, temporal dependence arises from observations before the mid-seventeenth century—suggesting that the decision of when to harvest grapes was influenced by the date of last year's harvest—and disappears after this when temperatures measured by thermometer are used. There are only two cases where departures from randomness are robust. The first is the

Mann, Bradley & Hughes (1999) Northern Hemisphere temperature series which, we have seen, had no explanatory power for cereal yields, and appears to be driven by variations in conditions at high latitudes where there is evidence of long swings in climate (Dawson *et al*., 2007). The second is the oak ring series which reflects the fact that oak tree are large, slow growing organisms (using innovations in oak ring thickness rather than actual thickness gave substantially identical results in predicting cereal yields). The estimated power spectra of all series except Northern Hemisphere temperature were flat.[9] In summary, then, Figure 6 and Table 6 show no long run trends in weather before the late twentieth century, and give no indication of a Medieval Warm Era or Little Ice Age. Instead, the annual observations are effectively independently, identically distributed for summer and winter temperature and rainfall.[10]

Our statistical analyses of these series finds little support for the claim that north-western Europe temperatures were subject to significant cooling between the thirteenth and nineteenth centuries. The picture, rather, is one of randomness without any long trends. We find low correlation in annual levels but high correlation in variance. That our findings run counter to the

[9] Regressions of annual weather conditions on dummies for each half century (not reported here) also show the instrumental weather series, oak rings and reconstructed Dutch series show no pattern, except perhaps for winters in the late seventeenth century, before the late twentieth century when winters become milder and wetter.

[10] Table 5 used summer temperature and tree rings because these series corresponded most closely with directly measured temperature and rainfall data in the period when data on the latter become available.

conventional wisdom on the Little Ice Age reflects our statistical approach. We analyse unsmoothed annual data, whereas the current practice in climatology is to smooth data using a moving average or other filter prior to analysis. When data are uncorrelated, as European weather series appear to be, smoothing can introduce spurious cycles, a phenomenon first described by Slutsky (1937). The intuitive reason for the Slutsky effect is straightforward: just as tossing a fair coin leads to long sequences with an excess of heads or tails, so random sequences in general will occasionally throw up some unusually high or low values in close succession. Such outliers, such as bad weather in the 1590s or 1690s, distort smoothing filters and create a misleading impression of changing climate. Figure 7 describes the effect in operation using the Burgundy grap harvest proxy for summer weather.

[Figure 7 about here]

Other data beside climate reconstructions support our reservations about the existence of a Little Ice Age. Firstly, the extent of major European glaciers shows little change between the sixteenth and nineteenth cneturies, after which they shrink rapidly (Figure 6[f]). Secondly, looking at demography we would expect northern Europe to have experienced weak population growth as the Little Ice Age contracted the margin of cultivation. In fact, the combined populations of the four Nordic countries probably more than doubled between 1500 and 1820 while that of Europe rose by less than half. Finally, focusing more narrowly on England, between 1450 and 1700 English agriculture saw neither the decline in the share of wheat in tillage acreage nor the relative decline in wheat yields that one might have expected.

Lamb and Fagan devoted considerable ingenuity to explaining many trends and events in European history through climate change. The task now is to seek complementary and alternative explanations for such trends and events. In the case of the collapse of Greenland's Nordic colony, for example, recent scholarship has de-emphasized the role of climate. Alternative potential explanations have been proposed, including competition for resources with the Inuit; the decline of Norwegian trade in the face of an increasingly powerful German Hanseatic League; the increasing availability of African ivory as a cheaper substitute for walrus ivory; the diversion of English fishing vessels from Greenland to Labrador and Newfoundland in the fifteenth century; overgrazing by livestock; bubonic plague; and marauding pirates (Roesdahl 1998; Seaver 2009). Moreover, the decline of wheat and rye cultivation in Norway from the thirteenth century may owe more to lower German cereal prices than any temperature change (Miskimin 1975: 59). Nor should too much be made of the imagined landscapes of Bruegel or Avercamp. Although the latter made a living from his lively if formulaic winter scenes, it must be said that such landscapes rarely feature in the work of other better known Dutch landscape artists such as Albert Cuyp or Jan van Goyen. Note too that Bruegel's much-reproduced 'Hunters in the Snow' (Lamb 1995: 233-34) was painted in the wake of the coldest winter in the Low Countries between 1435 and 1684.[11]

The alleged virtual disappearance of grape cultivation in late medieval England does not need a Little Ice Age either. England's grape acreage during the middle ages was miniscule: the forty-five vineyards recorded in the Domesday Book (1086) were for the most part recently planted, small in size, and catered mainly to the requirements of the Anglo-Norman nobility and to the church. Total output is unlikely to have exceeded 3,500 litres[12], implying a per capita consumption of close to zero. Nor is quality likely to have matched that of continental vineyards; indeed, some of the output was consumed as verjuice (a flavor-enhancing liquid made from unripe white grape varieties) rather than wine. Thus a more plausible explanation for the decline in English wine production is reductions in transactions costs that permitted England to pursue its comparative advantage. This is supported by the increasing importance of wine imports from France from the twelfth century on, until interrupted by the Hundred Years War (James 1951). It is also consistent with

[11] Even so it is just one of a cycle of *six* paintings describing different seasons of the year and none of the others hints at an LIA. Five survive, including the equally well-known 'The Harvesters', held in New York's Metropolitan Museum.

[12] The only yield reported in Domesday refers to the vineyard at Rayleigh, Essex, where six *arpents* yielded twenty *modii* in a good year (*si bene procedit*) (Darby 2007: 372). Assuming that the Domesday modius was the same as the Roman measure, this would imply about 30 litres per arpent. If the average vineyard had 3 *arpents* (about three acres) under grapes, then this implies a very rough aggregate estimate of 3,500 litres.

the much higher price of wine relative to beer in England: in the early fourteenth century a gallon of wine cost about 5 to 7 times as much as a gallon of ale in England, but in France the ratio was about one.[13]

In sum, we find no evidence for the case for climate change as an explanation for economic trends in early modern Europe.

4. *HIGH WAGES, DEAR LABOUR?*

Real wage trends, as measured by Allen and Clark, fail to capture the increase in living standards that must have taken place in England between the Middle Ages and Industrial Revolution. Real wage data are a more reliable guide to cross-sectional differences in living standards. But are they also a reliable measure of productivity differences? Allen (2009) implicitly believes they are, since he argues that in late eighteenth-century and early nineteenth-century England high wages, by inducing the necessary labour-saving technological changes or endogenous innovation, drove the Industrial Revolution. The hypothesis—echoing Habakkuk (1962) on Anglo-American comparisons—consists of two claims. The first is that real wages were high in England relative to elsewhere. The second is about the link between wages and induced labour-saving technical change. Our concern in this final section of the paper is with the first hypothesis.

[13] Compare Dyer 1989: 58, 62; Unger 2004: 74-77.

Data produced by Allen are consistent with Arthur Young's claim in the wake of his French travels in 1787-89 that in the agricultural sector *nominal* wages in England were almost double those in France (£33.5 versus £19). Deflating these wages by the respective prices of bread would erode much of the difference, Young conceded, but would not be legitimate because 'in England the rate of labour, supposing it to depend on provisions, would certainly depend, not on bread only, but on an aggregate of bread, cheese, and meat' (Young 1793: II, 315-16). Despite this, Young was not convinced that French labour was proportionately cheaper than English, because 'strength depends on nourishment; and if this difference be admitted, an English workman ought to be able to do half as much work again as a Frenchman'. So were wages in Britain really that 'high'?

4.1. Heights and wages

Young did not pursue the issue further, but data on adult heights in England and France c. 1800 support his assertion that British workers were physically stronger than French. Figure 8 describes the average heights of French army recruits and English male convicts (Weir 1997: 191; Nicholas & Steckel 1991). Both sets of data refer to cohorts born between 1780 and 1815. I have added 1 cm. to the French heights to reflect the fact that they refer to recruits who had not yet reached full adult height.[14] The comparison suggests that the gap between French and English heights on the eve of the Industrial

[14] They were aged 20-21 years.

Revolution was considerable—about four centimetres. Moreover, if socially more representative data for England were available (i.e. not just transported convicts, who came disproportionately from poor backgrounds), the likelihood is that the gap would be wider still (compare Fogel 2004: 13).

[Figure 8 about here]

The significant height advantage of British workers meant that they were physically stronger and more productive than their French counterparts. Current physiological research documents the link between height and grip or muscle strength.[15] But how much did height matter for productivity? There is no direct answer, but the development economics literature provides ample evidence that taller workers earn higher wages. Individual heights are partly genetically determined, and partly the product of human capital, education and net nutrition in childhood and adolescence. In a series of studies based on modern African and Brazilian individual-level data, Schultz (2002, 2005) finds

[15] For example, a recent study of Indian female labourers implies an elasticity of about two between height and grip strength (recorded in kilograms), while a study of champion weightlifters finds that weight lifted 'varied almost exactly with height squared', again suggesting an elasticity of two between height and strength (Shyamal *et al*. 2009; Ford *et al*. 2000).

that every additional centimeter in height is associated with a gain in wage rates of 'roughly 5-10 percent'.[16]

If a similar relationship between heights and productivity held two centuries ago, then the reported 4 cm. Anglo-French heights gap would have entailed a gap of 20-30 per cent in wage rates. This would account for a significant proportion—though not all—of the real wage gap. This finding also suggests that two centuries ago the causation ran from nutrition and health to wages, and not vice versa.

4.2. Piece rates and productivity

The link between heights and wages also implies that English workers generated more output per period worked than their French counterparts. We can address this through an analysis of piece rates and day rates in French and English agriculture, along the lines separately pursued by Clark for England and George Grantham for France two decades ago (Clark 1987; 1989; 1991; Grantham 1991; 1992; Mokyr 1991). Clark combined historical data on time-rates and piece-rates in a range of employments to infer contrasting labour intensities in England and elsewhere. On the basis of a comparison of labour requirements in reaping and threshing, Clark argued that worker productivity was constant in England between the sixteenth century and the nineteenth. Low and unchanging productivity in English agriculture over several centuries

[16] Gao and Smyth (2009), using contemporary urban Chinese wage data, report that 'each additional centimeter of adult height is associated with wages being 4.8 per cent higher for males and 10.8 per cent for females'.

was the product of culture, not institutions (Clark 1991). In defending the results of his analysis Clark (1989: 990) held that factors such as 'technology, the amount of land, horse power, and capital available, the institutional structure, and nutrition' did not constrain the pace of completing simple manual tasks such as reaping and threshing. Productivity differences therefore 'came as much from within the peasantry as from without'.

Here we follow Clark's lead in inferring productivity from the ratio of piece to time rates, but assume instead that productivity was limited by nutrition and height. Wages differed not just between England and France; they also differed significantly within both countries. The gaps between wages in French regions were greatest, so we focus here them. Analysis of official surveys conducted in the 1790s and 1800s suggests that there were 'two Frances: one of low wages and payments in kind in the northwest, south, and southwest, and another of middling or high wages in the north… and even the centre' (Crébouw 1986: 733-39: my translation). Thus while in the Paris region c. 1790 a worker might have earned enough to buy a quintal of wheat in 6 to 6.5 days, in Brittany it would have taken double that (Crébouw 1986: 740). That gap had not narrowed by 1840, when agricultural wages by département become available.

What of productivity? Grantham (1992: 362-63; 1993) has usefully documented the number of man-days required to perform certain key tasks in the cultivation and harvesting of wheat in seven French regions between the eighteenth and twentieth centuries. These regions—which he defined as Paris, Brittany, Berry, Champagne, West, Lorraine, and Nord—lay in the northern half on France; in spatial terms they include about half of the hexagon. Here I focus on three piece-rate measures provided by Grantham for the 1800-1850 period. The first measures the number of days it took to prepare the soil. The second is the total cost in man-days of growing and harvesting a hectare of wheat. The third is the cost in man-days of producing a hectolitre of wheat. The distinction between the second and third measures matters because wheat yields per hectare varied considerably across the seven regions. The coefficient of variation of the cost per hectolitre was considerably higher than that of the cost per hectare.

Some of Grantham's estimates are summarized in Tables 7a and 7b. They show that, calculated in terms of man-days per hectare, labour productivity c. 1800 was highest in the Champagne, Lorraine, and Nord regions and lowest in Brittany and the West. One would expect workers to have been taller and better workers in the former regions than in the latter two centuries ago. Were they?

[Tables 7a and 7b about here]

Data by *département* on the average height of conscripts recruited between 1819 and 1826 and on the proportion who were deemed 'small' are available (Aron *et al*. 1972: 92-93). In both cases regional height is taken to be the arithmetic mean of the estimates for the relevant *départements*. Table 8 relates these heights data to Grantham's measures of labour requirements in the seven farming regions. The correlations between height and measures of productivity are very high. They would be higher still if Brittany (where productivity was high relative to height) was excluded. The implied elasticities are huge, but we have not controlled for likely differences due to soil quality (other than the distinction between 'light' and 'stiff'), capital equipment, or other forms of human capital.

The scatter-plot in Figure 9 describes the correlation between the average heights of recruits in the 1820s and agricultural wages in 1840 across *départements* (Aron *et al*. 1972; Le Roy Ladurie & Demonet 1980). Table 9 reports the results of regressing agricultural wages in 1840 (*W40*) on average height (*HT*). We also use as explanatory variables the percentage literate (*LIT*), and the percentage of recruits suffering from iodine deficiency (*GOITRE*). The deleterious effects of iodine deficiency on health are well known; they 'begin before birth [and] include detrimental effects on brain development, stillbirths, increased infant and child mortality, and growth abnormalities'. Today goitre is the leading preventable cause of mental retardation globally (Sebotsa *et al*. 2003). We use natural log values of *LIT* and *W40*; the other variables are measured as percentages. Table 4 suggests that *LIT* and *GOITRE* have effects on *W40* that are in the expected direction and independent of *HT*. But after controlling for them, the implied impact of height on wages is still significant; an elasticity value of 8, for example, means that a gap of about one centimetre in height entailed a gap of about 5 per cent in wages, which is similar (same order of magnitude) to the previous estimate in last section.

[Tables 8 and 9 about here]

Returning to English agriculture, Clark (1991: 449) estimated the cost of reaping wheat from scattered but plentiful evidence in the reports prepared for the officially funded Board of Agriculture in the 1800s. The average of the forty-four observations found by Clark is 2.9 man-days per acre (or 7.2 days per hectare). This estimate tallies with data collected by agronomist Arthur Young on his agricultural tours of England over three decades earlier. Dividing the median costs of reaping an acre of wheat (60d) by the median harvest wage (20d-22d per diem) on both Young's southern and northern circuits yields a rate just short of three days per acre (Young 1771: IV, 293-96; 1772). Given that piece-workers earned more than 'the weekly pay of the country' (1771: IV, 296), this calculation probably biases our estimate of the productivity of harvest labour downwards. Young would probably not have objected to a rate of 7 man-days per hectare. This indicates a considerable advantage over France. In Grantham's regions about this time the cost in man-days ranged from 9.3 man-days per hectare in the relatively advanced Nord region to 16.3 man-days per hectare in economically backward Brittany. The average cost, weighted by output share, was 12.9 man-days per hectare (Grantham 1992: 362).

Clark (1991: 449) similarly estimates the output of a day's threshing at 0.236 man-days per bushel, which converts to 0.65 man-days per hectolitre.

Grantham’s estimates for his seven regions range from 0.9 man-days to 1.25 man-days per hectolitre, or nearly double the English rate.

In sum, England’s competitive ‘disadvantage’ in terms of time-rates on the eve of the industrial revolution was matched, if not more than matched, by its edge in output per unit of time. By this reckoning English wages, at least in agriculture, were ‘high’ but labour was not ‘dear’. English workers were paid more because they were stronger and more able.

5. *CONCLUDING REMARKS*

The past decade or so has seen a synergistic link developing between economic history, on the one hand, and growth and development economics, on the other. One by-product has been to push the search for the origins of modern economic growth further back in time which, in turn, has led to increased interest in the quantification of economic phenomena in the early modern period. This paper is an extended comment on some of the resultant data and their interpretation. It began by describing how new medieval English demographic data implied a strong ‘Malthusian’ response to real wage shocks. In seeking to reconcile medieval and later demographic regimes, it then pointed to evidence for a rise in living standards in the pre-industrial era, thereby casting some doubt on real wage time-series as a measure of trends in living standards. Next, it explored, and found wanting, the asserted link between living standards and climate change in the early modern era.

This rules out the need for a decline in food production and the diversion of resources to keeping people warm as posited by supporters of a dramatic cooling trend from the fourteenth century on. Finally, the paper drew attention again to a second limitation of wage data. Comparative analysis of height and work intensity seemed to confirm Clark's reservations about wage comparisons as gauges of relative competitiveness. It also reinforced the implication that the English economy had been subject to differential productivity growth in the pre-industrial era.

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Table 1: Effect of real wages and past mortality on inheritances, 1263–1348									
	Wage. L1	*Inherit. L1*	*Inherit. L2*	*1289*	*1317*	*1318*	*1342-44*	'R^2'	Loglik
20	-.586 [.104]	.044 [.012]	.033 [.012]	.426 [.088]	.558 [.080]	-.483 [.117]	.323 [.063]	.473	-794
All	-.485 [.091]	.027 [.008]	.018 [.007]	.418 [.078]	.600 [.069]	-.414 [.099]	.298 [.053]	.595	-1483

Multilevel Poisson regression of number of inheritances on lagged inheritances and real wages of agricultural labourers (in logs) by year from 1263 to 1348, with dummies for years of unusual mortality. Observations of lagged inheritances of zero are set to 0.001. There are 927 observations for the 20 largest manors, and 1,858 for the entire group of 66. 'R^2' is the squared correlation between fitted and actual values. Intercepts not reported, se's in parentheses.

Table 2: Likelihood of 'back-to-back' harvest failures, England 1268-1480

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 3. Gregory King on English incomes c. 1688			
	Population (M.)	£ per head	Y
Cottagers/paupers	1.018	2.0	2.04
Labourers/outservants	0.997	4.3	4.29
Others	3.684	13.1	48.26
Total	5.689	9.57	54.44
Source: Lindert and Williamson 1982			

Table 4: England/Great Britain, annual variations in grain yields

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	GB	31.26	2.227	0.071
Barley	1884-1939	GB	33.00	1.786	0.054
Oats	1884-1939	GB	40.14	1.810	0.045

Note: the standard deviations were estimated after the chronologies had been de-trended 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.

Table 5. Cereal Yields and Weather, 1211-1500								
	Intercept	Summer	Rings	Loglik	R^2	σ_α	N	Manors
Wheat	1.2227 **	0.0503 **	-0.0565 **	-2389	.296	0.2042	8439	112
Rye	1.286 **	0.0483 **	-0.0321 **	-597.2	.133	0.1372	1134	29
Barley	1.1805**	0.0035	-0.0087 **	-2231.4	.248	0.1934	7572	104
Oats	0.8742 **	0.0201	-0.0042	-2648.2	.152	0.1417	8290	116

Mixed effects regression of log cereal yield ratio on estimated summer temperatures (deviation from mean value of 15.3 Celsius) and oak ring thickness. Intercept varies across manors: σ_α is its standard deviation. N is number of observations and Manors is the number of manors. R^2 is the pseudo-R^2 for each regression. * denotes significance at 5 percent, ** at 1 percent.

Table 6: Summary statistics for annual weather until 1900							
	Start	Mean	SD	ρ	SE	R^2	L-B
	Temperature						
English Summer	1660	15.26	0.79	0.102	0.065	0.010	0.111
English Winter	1660	3.49	1.35	-0.031	0.065	0.001	0.626
Dutch Summer	1200	16.25	0.93	0.121	0.038	0.015	0.001
Dutch Winter	1200	1.73	1.62	-0.031	0.038	0.001	0.410
Burgundy Summer	1340	-0.09	0.98	0.152	0.043	0.023	0.000
N. Hemisphere	1200	-0.14	0.12	0.615	0.03	0.38	0.000
	Rainfall						
English Summer	1720	444.93	87.79	0.114	0.087	0.013	0.183
English Winter	1720	461.89	86.21	0.02	0.087	0.000	0.182
Oak Rings	1200	0.02	1.00	0.331	0.036	0.109	0.000

Mean, standard deviation, and autoregressive coefficient, standard error and R2 for historical weather series. L-B is the p-value of the Ljung-Box test for randomness.

Table 7a. Harvest and threshing costs in man-days per hl.: wheat c. 1800							
Region	*Pre-harvest (light)*	*Pre-harvest (stiff)*	*Manuring*	*Harvest*	*Threshing*	*Total (light)*	*Total (stiff)*
Paris	24.7	13.6	7.4	12.9	13.5	58.5	47.4
West	31.5	18.0	3.5	14.0	12.5	61.5	48
Bretagne	33.5	20.0	4.7	16.3	15.0	69.5	56
Berri	32.0	18.5	3.0	13.8	11.25	60.05	46.55
Champagne	17.5	10.0	4.0	13.0	9.0	43.5	36
Lorraine	18.5	10.5	4.0	13.0	9.0	44.5	36.5
Nord	11.9	7.1	9.0	9.3	15.3	45.5	40.7
Note: Threshing costs estimated by multiplying yield by man-days per hectolitre							

TABLE 7b. Cost per hectare and per hectolitre: wheat in man-days c. 1800				
	Cost per hectare		Cost per hectolitre	
Region	*Light*	*Stiff*	*Light*	*Stiff*
Paris	58.5	47.4	3.01	3.63
West	61.5	48	5.17	6.67
Brittany	69.5	56	4.57	5.49
Berry	60.05	46.55	5.05	6.50
Champagne	43.5	36	3.48	4.19
Lorraine	44.5	36.5	3.08	3.69
North	45.5	40.7	2.34	2.62
Source: Table 2(a); Grantham 1993: 483				

TABLE 8: Correlations between height and measures of labour productivity				
	Average height		Percentage 'small'	
	Light	Stiff	Light	Stiff
Pre-harvest	-.846	-.812	.847	.810
Hectare	-.780	-.732	.817	.771
Hectolitre	-.851	-.885	.857	.891
Sources: Grantham 1993; Aron *et al*. 1972: 86-87, 92-93.				

TABLE 9. Heights and Wages in French départements c. 1825-1840			
	[1]	[2]	[3]
HT	15.09 (2.46)	9.67 (3.43)	9.28 (3.41)
LIT		.0041 (.0015)	.0048 (.0015)
GOITRE			-.0465 (-.021)
Constant	-2.626 (-1.25)	-.036 (1.70)	.169 (1.69)
N	86	73	70
Rsq Adj	0.3011	0.3612	0.3918
Source: Aron *et al*. (1972); wage data from Gilles Postel-Vinay. Standard errors in parentheses.			

Figure 1. Real Wages in Agriculture, 1200s-1860s

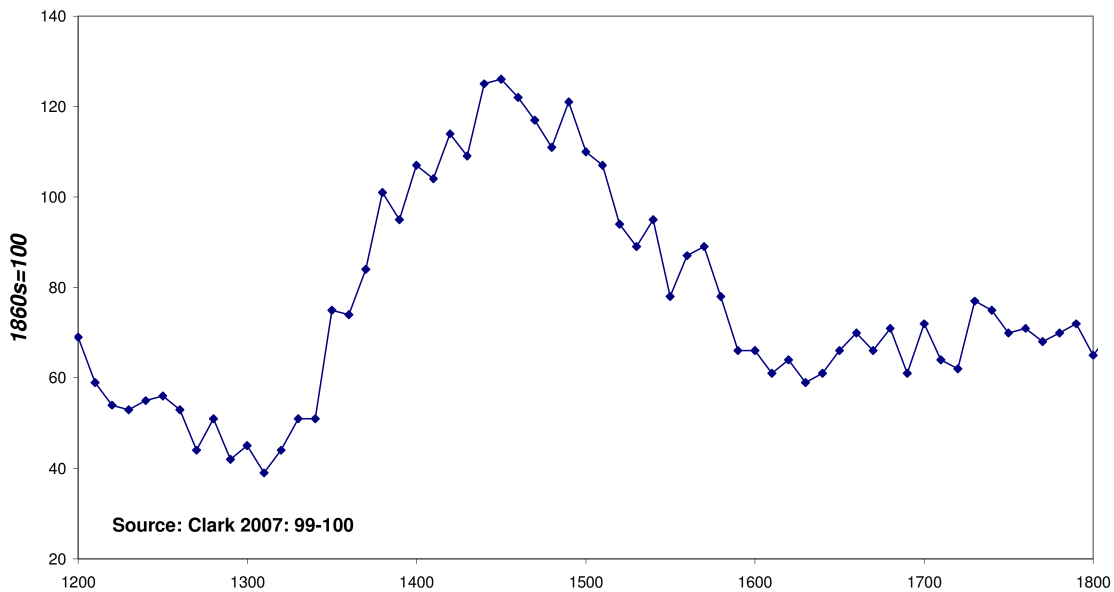
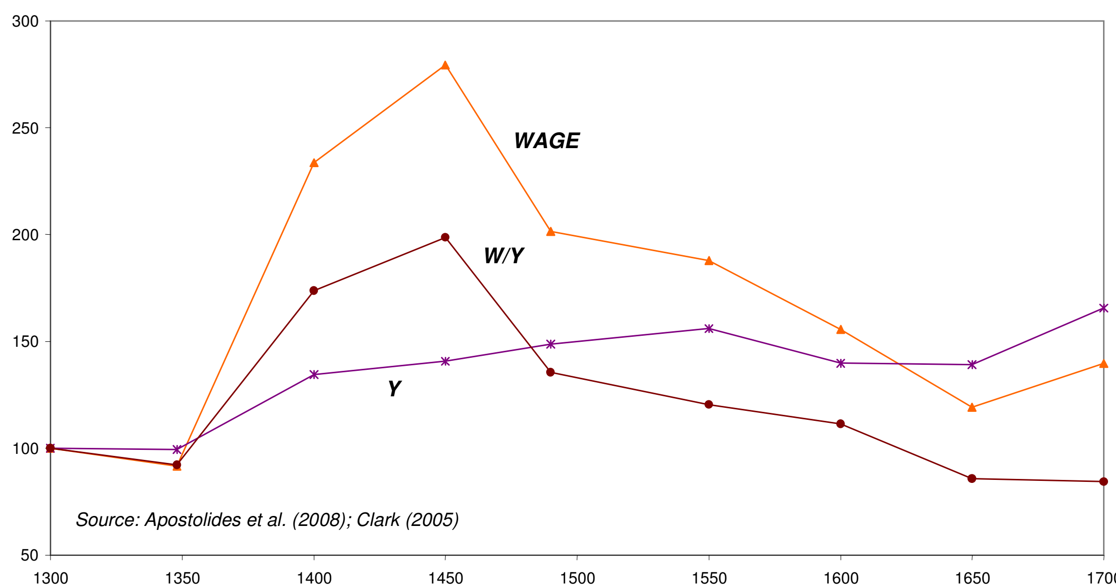
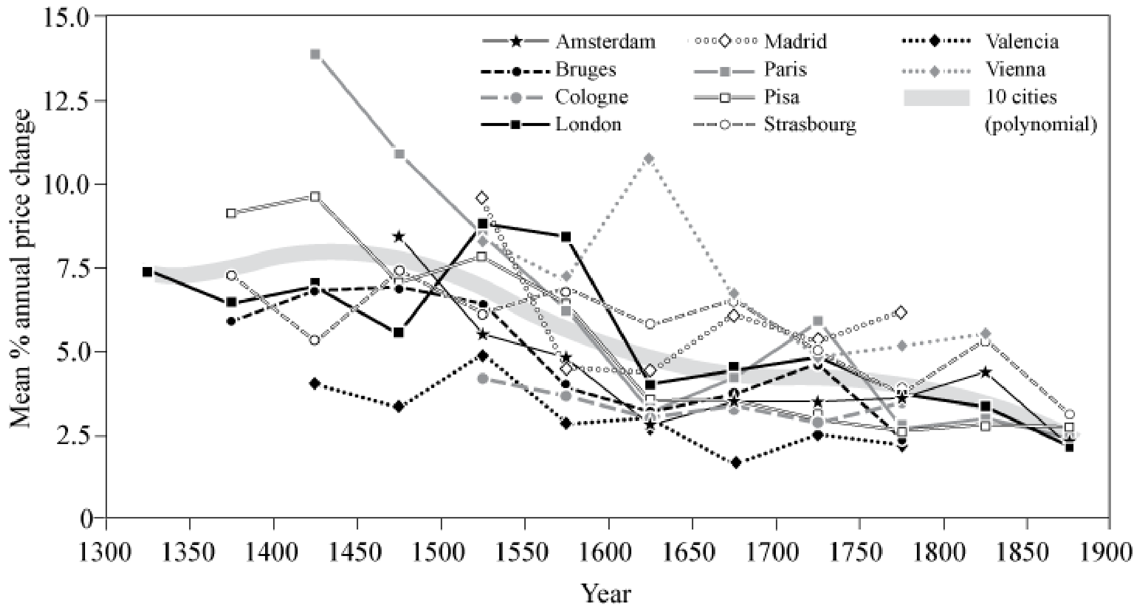


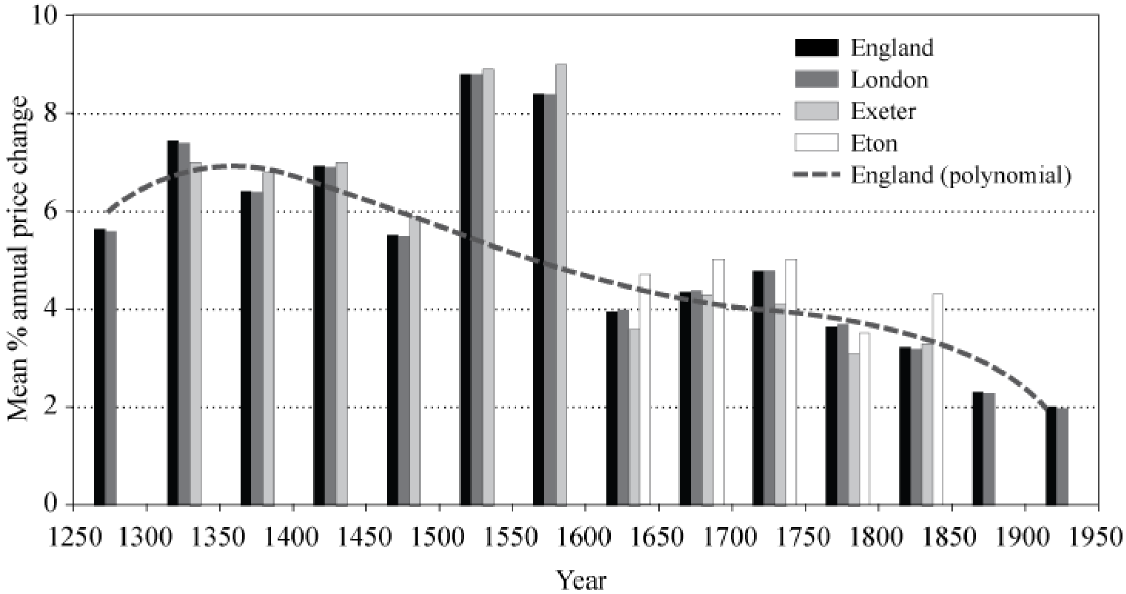
Fig. 2. Wage and GDP per Head 1300-1700





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, Paris, Pisa, Strasbourg, Madrid, Valencia, and Vienna are those given in the Allen—-Unger Database.

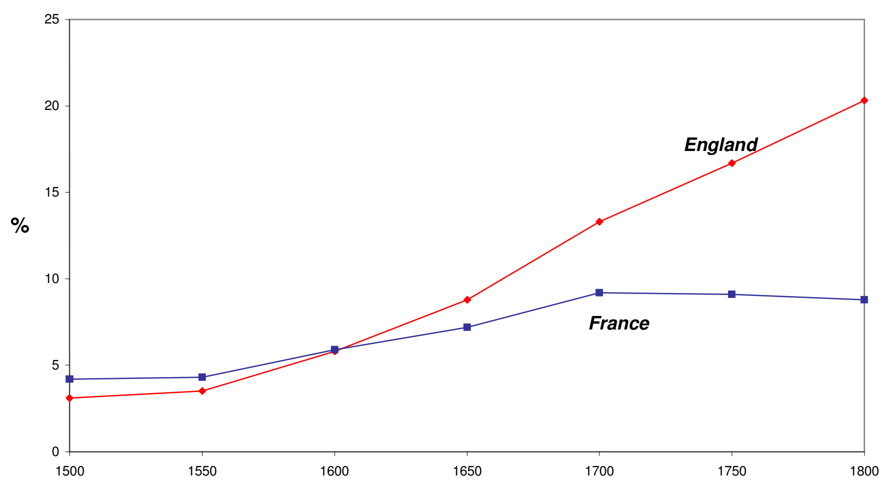
Figure 3: Wheat price: mean annual percentage change in ten European urban markets, 1300-1899.



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*. To highlight how anomalous are the sixteenth-century figures, they have been excluded from the polynomial.

Figure 4: Wheat price: mean annual percentage change in England and three English urban markets, 1260-1914.

Figure 5. Urbanization in France and England, 1500-1800



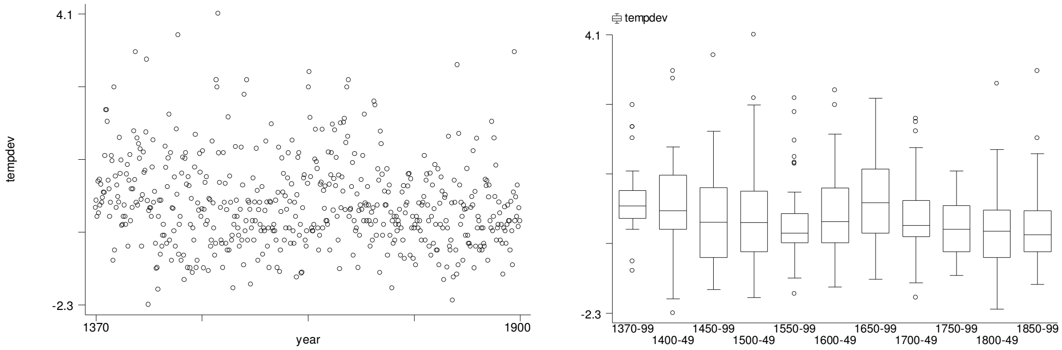


Figure 6[a]. Burgundy Grape Harvest Index, 1370-2000

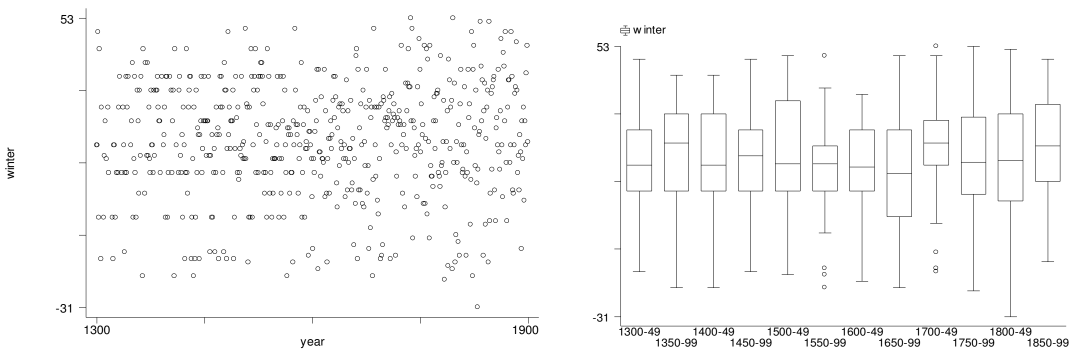


Figure 6[b]. Low Countries Winter Temperatures, 1300-2000

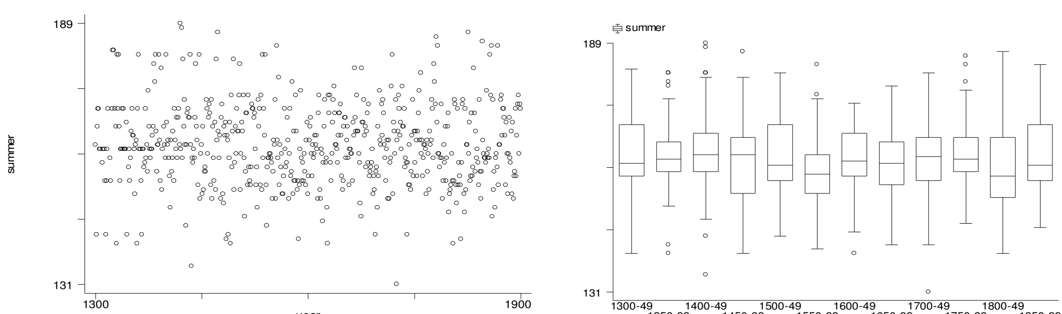


Figure 6[c]. Low Countries Summer Temperatures, 1300-2000

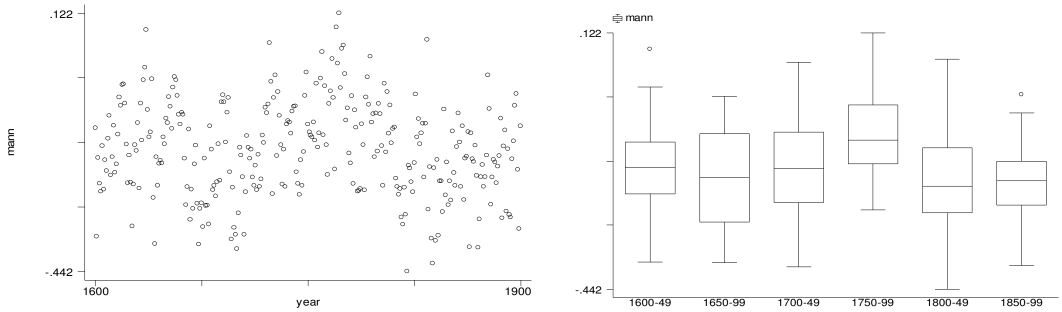


Figure 6[d]. Mann *et al*., 1600-1990

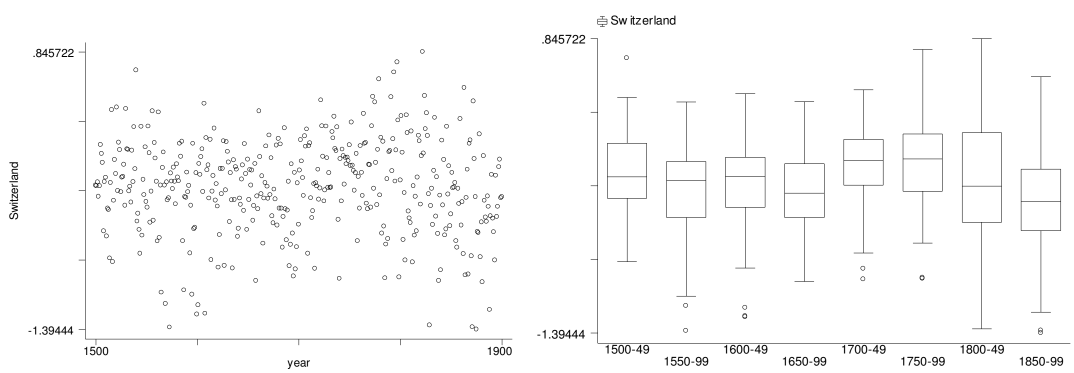
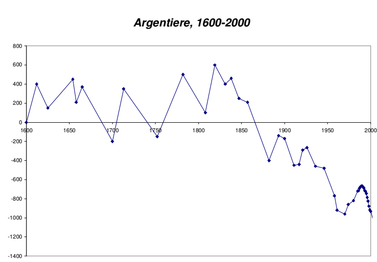
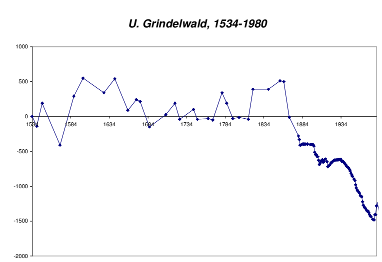


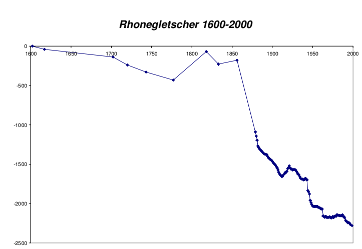
Figure 6[e]. Switzerland, 1500-1900



[a] Argentière



[b] U. Grindelwald



[c] Rhonegletscher

Figure 6[f]. Glacier Lengths, 1500-2000

Figure 7: Burgundy 1370-2000

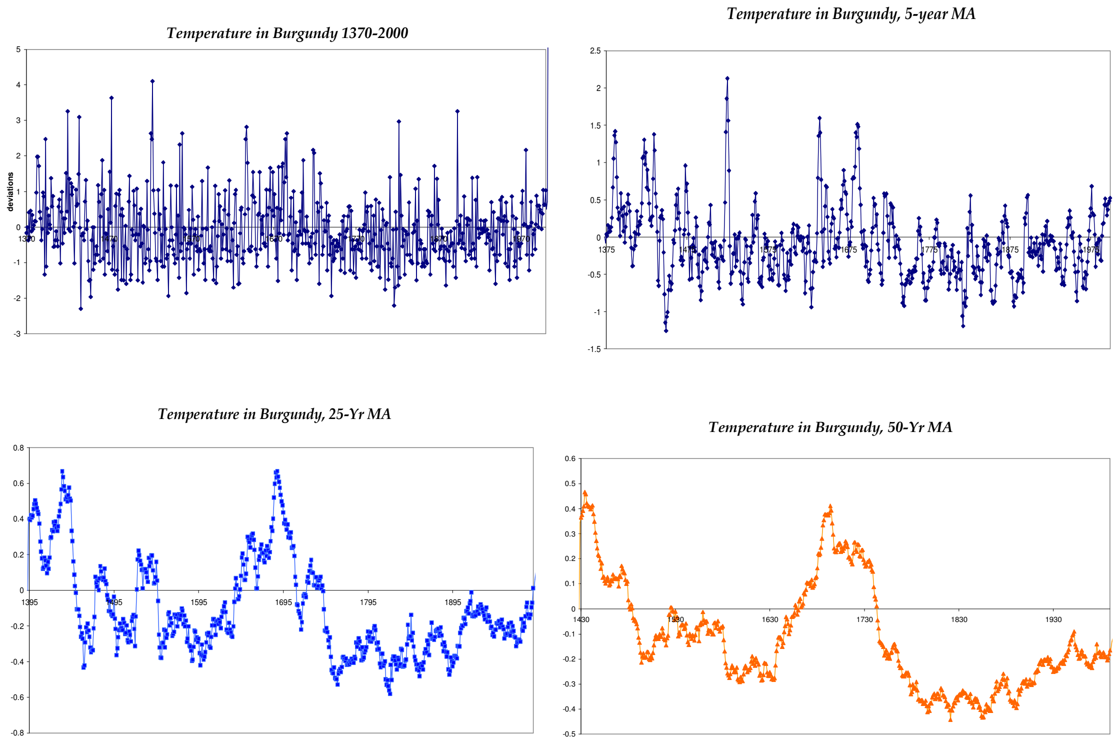


Figure 8. English and French Adult Male Heights, Cohorts Born 1780-1815

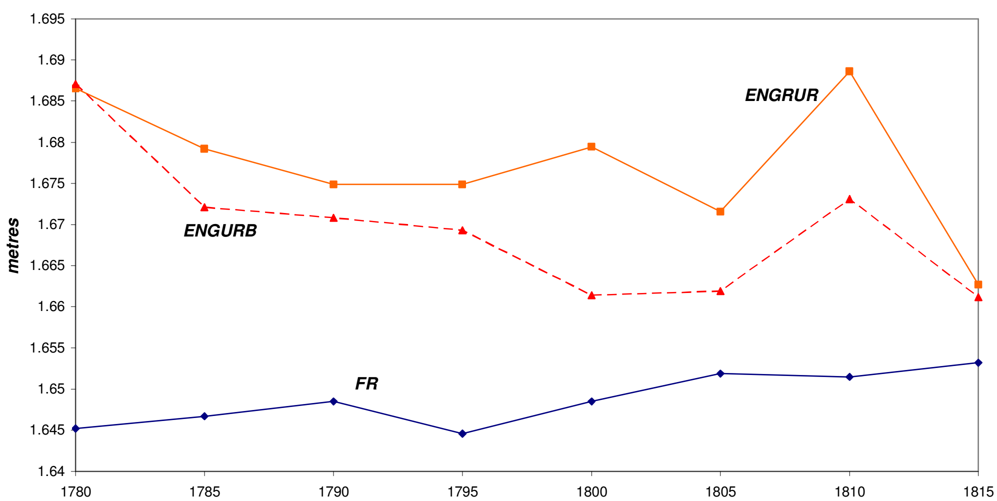


Figure 9. Wages and Height by Département c. 1840