Title	Debating the Little Ice Age
Authors(s)	Kelly, Morgan, Ó Gráda, Cormac
Publication date	2014-03
Publication information	Kelly, Morgan, and Cormac Ó Gráda. “Debating the Little Ice Age” (March, 2014).
Series	UCD Centre for Economic Research Working Paper Series, WP14/06
Publisher	University College Dublin. School of Economics
Item record/more information	http://hdl.handle.net/10197/5482

UCD CENTRE FOR ECONOMIC RESEARCH

WORKING PAPER SERIES

2014

Debating the Little Ice Age

Morgan Kelly and Cormac Ó Gráda, University College Dublin

WP14/06

March 2014

UCD SCHOOL OF ECONOMICS
UNIVERSITY COLLEGE DUBLIN
BELFIELD DUBLIN 4

Debating the Little Ice Age

Morgan Kelly and Cormac Ó Gráda[1]

ABSTRACT: This paper replies to commentaries by Sam White and by Ulf Büntgen and Lena Hellmann on our 'The Waning of the Little Ice Age: Climate Change in Early Modern Europe'. White and Büntgen/Hellmann seek to prove that Europe experienced the kind of sustained falls in temperature between the fifteenth and nineteenth centuries that can justify the notion of a Little Ice Age. Neither of them adequately addresses the cogency of the anecdotal or statistical evidence presented in our article, especially with regard to the spurious peaks and troughs created by the smoothing of temperature series--the so-called Slutsky Effect.

Keywords: Little Ice Age, Climate Change, Economic History

JEL Classification: N, Q54

[1] Forthcoming *Journal of Interdisciplinary History*, XLV[1] (Summer, 2014). The authors thank Joel Mokyr for useful comments on an earlier draft. The usual disclaimer applies.

In two related articles, “The Waning of the Little Ice Age” and “Change Points and Temporal Dependence in Annual Weather Reconstructions: Did Europe Experience a Little Ice Age?” we examined, respectively, the documentary and statistical evidence for a Little Ice Age (LIA) in Europe, finding little hard evidence to support the widely held belief that Europe experienced sustained falls in temperature between the fifteenth and nineteenth centuries. The commentaries of White and of Büntgen and Hellmann in this journal leave us just as skeptical as before. Although White engages vigorously, if less than coherently, with the documentary evidence that we present, the more measured contribution of Büntgen and Hellmann simply rehearses existing evidence that purports to show a European Little Ice Age without attempting to address any of the statistical issues that we raise. Although a central theme of our two articles is that smoothing temperature series can give rise to spurious peaks and troughs that can be mistaken for a Little Ice Age--the so-called Slutsky Effect--in refutation of our findings, Büntgen and Hellmann with delicious, albeit unconscious, irony simply present a series of smoothed series without once mentioning, let alone discussing, the Slutsky Effect. [2]

THE LITTLE ICE AGE ACCORDING TO WHITE If White is to be believed, our arguments are not merely wrong (reading his piece brings to mind Mary McCarthy's dismissal of Lillian Hellman--“Everything she writes is a lie, including 'and' and 'the'”) but intellectually dishonest. Whipping himself to a climax of indignation and scorn he claims, "Kelly and Ó Gráda cite only one series, that compiled by Glaser and Rieman, that extends back far enough to capture the entire LIA in relation to the medieval period (again, only allowing for

[2] Kelly and Ó Gráda, “The Waning of the Little Ice Age,” *Journal of Interdisciplinary History*, XLIV(2013), 301-325 (hereinafter the documentary article, cited in text); *idem*, “Change Points and Temporal Dependence in Reconstructions of Annual Temperature: Did Europe Experience a Little Ice Age?” working paper 2012/10 (University College Dublin Centre for Economic Research, 2012), available at www.ucd.ie/economics/research (hereinafter the statistical article); Sam White, “The Real Little Ice Age,” *Journal of Interdisciplinary History*, XLIV (2013), 327-352 (hereinafter cited in text); Ulf Büntgen and Lena Hellmann, “The Little Ice Age in Scientific Perspective: Cold Spells and Caveats,” *ibid*., 353–368 (hereinafter cited in text).

generous inferences from limited records until c.1400). This reconstruction is conspicuously absent from Kelly and Ó Gráda's charts of historical series (see Figure 3 of their article in this issue)—no doubt because it clearly suggests that the period between roughly 1400 and 1900, apart from a mild phase in the mid-1700s, was distinctly cooler on average than the centuries before or after" (White, 335).

However, it might be better to look at what we actually wrote about that series. Had White bothered to read the statistics paper, as he claims to have done, he might have noted that we devote an entire section to an analysis of this series by Glaser and Reiman. Figure 1 reproduces a shortened form of the diagram that we presented in the statistics paper. It shows the probabilities of a good year, conditional on the previous year being good, and of a bad year, conditional on the previous year being bad. The eleventh and twentieth centuries at either end stand out from the rest. That the twentieth century has a higher probability of good winters and successive good winters than do earlier centuries is consistent with global warming. In the centuries between the two, the probability of good or bad winters appears fairly constant, as does the probability of a bad winter being followed by a bad one. The probability of good winters following good winters is also fairly constant, except for that of the seventeenth century, which is nearly 20 percent higher than those of the surrounding centuries, despite being in the depth of the supposed LIA. Note, however, that the credible intervals (or Bayesian confidence intervals) overlap with other periods. For summers, the probability of a good summer, or of successive good or bad summers, is fairly constant. The probability of bad summers is slightly lower in the twelfth and thirteenth centuries, and higher in the nineteenth century, but, again, the credible intervals overlap with other centuries. The point is by no means to deny the possibility of occasional clusters of bad years; in fact, the statistical article drew attention to the 1810s, the 1590s, and the 1690s, in particular. [3]

[3] Rüdiger Glaser and Dirk Riemann, "A Thousand Year Record of Climate Variation for Central Europe at a Monthly Resolution," *Journal of Quartenary Science*, XXIV (2009), 437–449.

[INSERT FIGURE 1 ABOUT HERE]

Unfortunately, neither the tone nor intellectual level of White's criticisms improves thereafter. After dubbing narratives linked to the LIA, such as the demise of the Norse Greenland colonies and English vineyards, "red herrings," White devotes nearly half of his commentary to defending interpretations of them that are consistent with an LIA. We view these narratives, mostly due to Lamb, as circumstantial evidence, not as "proofs" of the LIA. On this score, White seems to agree (White, 336, 338), though not consistently (see below). As rhetorical devices, they continue to exert considerable power and hence must be disarmed. [4]

Norsemen and Others In the documentary article, we argued that the paucity of hard data leaves room for several plausible but still nonfalsifiable explanations for the demise of Greenland's Norse colonies. In addition to the LIA, we discussed six others that could account for the flimsy evidence available. The literature on the topic continues to accumulate. Since our article went to press, a new study by Arneborg, Lynnerup, and Heinemeier also denies that climate cooling forced the hand of the colonists. Their skeletal analysis indicates that the last colonists were neither stunted nor diseased. "Perhaps," summarizes Linnerup, "they were just sick and tired of living at the ends of the earth and having almost nothing but seals to eat."[5]

Both seals and a change in climate feature in another article of 2012, this one by Dugmore et al., in which several factors that we also mentioned play a role: (1) increasing conflict with indigenous inhabitants, whom the colonists called "Skraelings" ("now the Skraelings have desolated

[4] See Hubert H. Lamb, *Climate, History and the Modern World* (London, 1995; orig. pub. 1982); *idem*, "The Early Medieval Warm Epoch and Its Sequel," *Palaeogeography, Palaeoclimatology, and Palaeoecology*, I (1965), 13-37; *idem*, "Britain's Changing Climate," *Geographical Journal*, CXXXIII (1967), 445-466.

[5] Jette Arneborg, Niels Lynnerup, and Jan Heinemeier, "Human Diet and Subsistence Patterns in Norse Greenland AD c. 980-AD c. 1450: Archaeological Interpretations," *Journal of the North Atlantic*, III (2011-2012), 119–133; Günther Stockinger, "Abandoned Colony in Greenland: Archaeologists Find Clues to Viking Mystery," *Der Spiegel Online*, January 10, 2013, available at http://www.spiegel.de/international/zeitgeist/archaeologists-uncover-clues-to-why-vikings-abandoned-greenland-a-876626.html (accessed October 1, 2013).

the whole western settlement," as one mid-fourteenth-century source reported); (2) the marginalization of Greenland when Norway began to shift its focus to the south and east; (3) the declining importance of the trade in walrus tusks; and (4) the tiny size of the settlements (a single Inuit raid in 1379 A.D. may have deprived the colony of 5 percent of its hunters). Regular commercial contacts with Norway virtually ceased decades before the collapse of the eastern colony; the smaller western colony seems to have disappeared before any evident cooling in the supporting meteorological data. Our basic point—which White obfuscates—remains that, apart from any climatic considerations, the settlement's existence was precarious. As Dugmore, Keller, and McGovern (whom we are accused of misquoting) concluded in their 2007 study, "One widely held view is that the impact of climate change, the failure of their pastoral subsistence base, and an inability to adapt were key factors in the end of Norse settlement in Greenland. Alternatively, as we argue here, unfavorable economic changes and falling populations might actually have been the key factors in increasing the settlements' vulnerability." We could not agree more.[6]

London's Frost Fairs White's view of the frost fairs is contradictory. On the one hand, he concedes that "no serious scholar" considers the two dozen frost fairs on the river Thames between c. 1400 and 1814 as "proof" of an LIA. On the other, however, he cites them as evidence of cooling, since the data "appear to predict" the seventeenth-century peak implied by Northern Hemisphere proxy trends (White, 344). We cannot help him if he chooses to interpret the much higher frequency of cold-weather extremes before 1900 as evidence for an LIA rather than for post-1900 global warming. White also skirts around our statistical point that frost fairs were much more likely during cold winters in the seventeenth and eighteenth centuries than during cold winters in the

[6] Andrew J. Dugmore et al., "Cultural Adaptation, Compounding Vulnerabilities and Conjunctures in Norse Greenland," *Proceedings of the National Academy of Sciences*, CIX (2012), 3658-3663, available at http://www.pnas.org/content/109/10/3658.full.The North Atlantic meteorological series underpinning the case made by Dugmore et al. is evidently stationary between c. 1150 and c. 1400, whatever it is thereafter. See Michael E. Mann et al., "Global Signatures and Dynamical Origins of the Little Ice Age and the Medieval Climate Anomaly," *Science*, CCCXXVI (2009), 1256-1260. Dugmore, Christian Keller, and Thomas H. McGovern, "Norse Greenland Settlement: Reflections on Climate Change, Trade, and the Contrasting Fates or Human Settlements in the North Atlantic Islands," *Arctic Anthropology*, XL(2007), 30.

preceding or following centuries.

Evidence of years when the river Rhône and Lake Constanz froze adds to the confusion since it suggests different chronologies (Figure 2). In the case of the Rhône, the fifteenth century was one of the mildest centuries of the second millennium, whereas the fourteenth century was the coldest. The number of *Seegfrörne* (lake freezings) on Lake Constance (Bodensee), however, peaked in the fifteenth and sixteenth centuries. Neither series registers the seventeenth-century peak in the number of freezings championed by White.[7]

The ambiguities inherent in these comparisons echo broader ambiguities about the dating of the LIA, which White exacerbates by proposing *three* distinct definitions of the "Real LIA" (1400-1850, 1310s-1810s, and c. 1580-c. 1710). The second and the third definitions are intended to capture the "human dimension" and the "human experience" of the LIA, respectively, but they serve only to allow the historian's tail to wag the climatologist's dog. The false precision of these dates, grounded in historical events, confuses secular trends and extreme years. White conflates the two—"LIA climate fluctuations brought clusters of extreme events" (White, 349)—but the events could easily have occurred without an LIA, as shown above.

[FIGURE 3 ABOUT HERE]

Hunting in the Snow Thanks to Lamb, Pieter Bruegel the Elder's "Hunters in the Snow" has become the iconic image of the LIA. But "Hunters," *pace* White, has no bearing on the LIA. Its strange mountainous landscape owes more to the influence of Simon Bening's "Flemish Calender" (c. 1515) than to any climate change in the Low Countries in Bruegel's day. In terms of content and iconography, Bruegel was following a well-defined "book of hours" tradition, traceable back to the Middle Ages; "Hunters" was one of a series of six calendar illustrations commissioned by

[7] Wolfgang Behringer, *A Cultural History of Climate* (London, 2010), 90-91; Maurice Jorda and Jean-Christophe Roditis, "Les épisodes de gel du Rhône depuis l'an mil: périodisation, interpretation paléoclimatique," *Méditerranée*, LXXVIII (1993), 19–30.

Antwerp merchant Nicolaes Jonghelinck in 1565. Two of the other illustrations, far from suggesting an LIA, have been described as a "radiant expression of high spring" and an example of "the flat glowing scenery [that] is pure midsummer."[8]

Nonetheless, Bruegel initiated a Flemish-Dutch fashion for winter landscapes, long after the supposed onset of the LIA; by the same token, the fading interest in this genre after c. 1675 owed less to climate change than to fashion, as the public wearied of gloomy representations of winter. The weather, as depicted in landscape painting during the Golden Age, owed more to "the stylistic requirements of the market" than to meteorological reality. Paintings were accordingly biased toward dramatic or fine weather and away from the humdrum grey clouds most commonly found in Dutch skies, then and now. The stock-in-trade of Hendrick Averkamp (1585-1634), who has become synonymous with the LIA, was joyful winter scenes, played out almost always "in calm and stable weather conditions with stratiform clouds." But the link between such art and the LIA is as tenuous as that between Irving Berlin's *White Christmas* and global warming.[9]

Population and Agriculture Turning from symptoms to consequences of the LIA, Lamb and his followers repeatedly claimed that the impact of the LIA was particularly severe in the colder, marginal areas of Europe. As temperatures dropped, "grain cultivation [in Iceland] had to be given up"; "farms in many [of Norway's]upland districts stood empty for hundreds of years"; and even in Denmark, "visitors to a royal wedding in 1406 reported much uncultivated, sodden land," lamenting

---

[8] Lamb, "Britain's Changing Climate," 461-462; Iain Buchanan, "The Collection of Niclaes Jongelinck: II The 'Months' by Pieter Bruegel the Elder," *Burlington Magazine*, 132[1049] (1990), 544; Timothy Foote, *The World of Bruegel* (New York, 1971), 176, 178, as cited in Philip McCouat, "The Emergence of the Winter Landscape: Bruegel and His Predecessors," *Journal of Art in Society* (2013), available at http://www.artinsociety.com/the-emergence-of-the-winter-landscape.html.

[9] Peter J. Robinson, "Ice and Snow in Paintings of Little Ice Age Winters," *Weather*, LX (2005), 38; John Walsh, "Skies and Reality in Dutch Landscape," in David Freedberg and Jan de Vries (eds.), *Art in History: History in Art: Studies in Seventeenth-Century Dutch Culture* (Chicago, 1991), 95-117; Franz Ossing, "Bilder als Klima-Archive?" *System Erde*, II (2012), 90-95. Michael O'Sullivan, "National Gallery of Art's 'Hendrick Avercamp: The Little Ice Age': A Frozen Gem," *Washington Post*, 26 March 2010; Franz Ossing and Pieter Roelofs, "Avercamp's Skies," contribution to the symposium "*IJspret: De winters van Hendrick Avercamp*," Amsterdam, January 14, 2012 (see <ebooks.gfz-potsdam.de/pubman/item/escidoc...1/.../AvercampH_e.pdf>).

that "wheat was grown nowhere." We addressed such claims indirectly through an analysis of population trends and agricultural yields. The ramifications of cooling should have been evident in demographic trends, particularly in the marginal parts of Europe. On the contrary, the "perfect storm of population pressures and rapid cooling" asserted by White did not prevent the populations of Scandinavia and Switzerland from increasing their share of the European total (White, 350). Similarly, the cooling associated with an LIA should have resulted in diminished cereal yields, especially in the case of the more cold-sensitive grains. We could find no such evidence in the most comprehensive inventory of cereal yields available. [10]

Nor is White's gambit of highlighting extreme years--1621 when the Bosphorus froze, 1658 when a Swedish army marched across the sound, or 1709 when French wine burst in its bottles--convincing. We could equally invoke the winter of 1941/42, when the extreme cold had important ramifications for the outcome of Word War II; that of 1947, when ice floes were seen off the East Anglian coast, and the Dover-Ostend ferry service was suspended due to pack ice off the Belgian coast; or the "big freeze" of 1963, when the sea froze six km out to sea from Dunkirk, and a car could be driven across the frozen Thames at Oxford. But what would such conditions prove? [11]

England's Vineyards In this case, too, White contradicts himself. On the one hand, he declares that our discussion of the demise of wine production in late medieval England is "irrelevant," with "no bearing" on climate cooling. On the other, however, he states that studies based on grape culture that point to "cooler summers in early modern Europe" are a "recurring

---

[10] Lamb, "Britain's Changing Climate," 455. The claim regarding wheat cultivation in Denmark is completely beside the point, since wheat was not grown there during the Middle Ages. See Peter Hambro Mikkelsen and Lars Christian Nørbach, *Drengsted: Bebyggelse, jernproduktion og agerbrug I yngre romersk og ældre germansk jernalder* (Højbjerg, 2003), 156-157 (citing H.A. Jensen, "Macrofossils and Their Contribution to the History of Spermatophyte Flora in Southern Scandinavia from 13000 BP to 1536 AD," *Kongelige Danske Videnskabernes Selskab Biologiske Skrifter*, XXIX (1987), 1-64). We are grateful to Peter Sandholt Jensen for these references.

[11] Alex J. Robertson, *The Bleak Midwinter 1947* (Manchester, 1987), 14; Andrew French, "So You Think This Is Cold?" *Oxford Mail*, 7 Jan. 2010; Kevin C. Kearns, *Ireland's Arctic Siege: The Big Freeze of 1947* (Dublin, 2012).

element in descriptions of freezing LIA winters and offer a good indicator of their severity" (White, 337).

England's retreat from winemaking, which was a key part of Lamb's classic case half a century ago, is now part of the conventional wisdom on the LIA. Our case—that wine production was always a marginal activity in England, that the quality of English wine was inferior, that the trade between England and western France entailed both regions to select their comparative advantage, and that, therefore, arguments invoking the LIA are redundant—stands. [12]

Glaciers White's rebuttal of our short discussion of growth and shrinkage of glaciers is the most confusing and contradictory of all. Rather than confront our evidence of stasis before the nineteenth century (Kelly and Ó Gráda, 320-322), which is not readily squared with a "cooling trend" lasting until c. 1850, he invokes Groves' unhelpful chronology, which times the main advances as "dating to around 1320, 1380, 1580 to 1610, 1690 to 1700, in the 1770s, around 1820 and 1850, in the 1880s, 1920s and 1960." The implication that cooling lasted well beyond 1850 should have alerted White to the possibility (as we noted) that higher winter precipitation brought by mild and humid winters may also have played a role, making the connection between temperature and glacier length hardly straightforward.[13]

THE LITTLE ICE AGE ACCORDING TO BÜNTGEN AND HELLMANN Our response to Büntgen and Hellmann is less involved because they do not address anything that we wrote. In fact, they barely

---

[12] Lamb, "Britain's Changing Climate," 455-457; *idem*, *Climate, History, and the Modern World*, 185. See also Brian M. Fagan, *The Little Ice Age: How Climate Made History, 1300-1850* (New York, 2001), 84; Gregory McNamee, "Little Ice Ages," *Encyclopedia Britannica blog*, February 2007, available at http://www.britannica.com/blogs/2007/02/little-ice-ages/; Marco Evers, "A Fine Drop: Global Warming Brightens the Outlook for British Wine," *Der Spiegel Online*, 13 Nov. 2009.

[13] Samuel U. Nussbaumer and Heinz J. Zumbuehl, "The Little Ice Age History of the Glacier des Bossons (Mont Blanc Massif): A New High Resolution Glacier Length Curve Based on Historical Documents," *Climatic Change*, CXI (2012), 301-334; Jean Grove, *Little Ice Ages: Ancient and Modern* (London, 2004; orig. pub. 1988), II, 562 (as cited in White, 343); Atle Nesje and Svein Olaf Dahl, "The 'Little Ice Age'--Only Temperature?" *The Holocene*, XIII (2003), 171–177; Nesje et al., "The 'Little Ice Age' Glacial Expansion in Western Scandinavia: Summer Temperature or Winter Precipitation?" *Climate Dynamics*,XXX (2008), 789–801.

refer to us, even less to our arguments, except occasionally to re-assert that we are wrong. Were their article an exam, we would be tempted to respond, "Answer the question asked."

In the statistical paper, we show that the four main documentary reconstructions of European weather over the past centuries do not reveal the trends or breaks that we would expect from a European Little Ice Age. Instead, the temperature series resemble white noise--independent draws from a distribution with a fixed mean and variance. In order to dispute our findings, Büntgen and Hellmann need to do one of two things—(1) to prove that the series that we analyze, which have been constructed by leading European climatologists, many of whom have co-authored papers with Büntgen and Hellmann, are wrong or (2) that our statistical analysis, in particular the powerful martingale difference tests that form the analytical core of the statistical paper, is deficient. Büntgen and Hellmann attempt neither of these strategies. Instead, they present a number of studies that purport to show systematic drops in European temperature during the past few centuries. But there are two problems with most of these studies, both of which Büntgen and Hellman ignore: They are largely based on tree rings, and the data are smoothed.

Climatologists have gone to considerable effort to reconstruct documentary weather series for Europe rather than using tree rings because tree rings are not a reliable proxy for weather in most parts of Europe. Tree rings reflect weather only at the limits of a tree's geographical range where it is under constant stress due to aridity or cold. In Europe, this fact limits their usefulness to high mountains or northern Scandinavia--hence, the importance of documentary evidence. The use of tree rings is subject to further reservations, even regarding the reconstruction of weather in areas of climatic stress. Examining a database comprised of most of the tree-ring series (and a few other proxies) that climatologists employ, McShane and Wyner find that the correlation of these series with instrumental temperature records since the nineteenth century is extremely low, thus questioning the validity of tree rings as a proxy for historical weather. [14]

[14] Blakeley B. McShane and Abraham J. Wyner, "A Statistical Analysis of Multiple Temperature Proxies: Are Reconstructions of Surface Temperatures over the Last 1000 Years Reliable?" *Annals of Applied Statistics*, V (2011), 5-44.

Büntgen and Hellmann raise one valid concern about documentary series--that, because they are spliced together and their averages likely to be set equally, break points would thereby be removed from the series. Yet, significant as this point may be, it does not apply to the martingale difference tests that are the main armament of our statistical article, which, because they find almost no temporal dependence in weather series, are not affected by such splicing.

[INSERT Figure 3 ABOUT HERE]

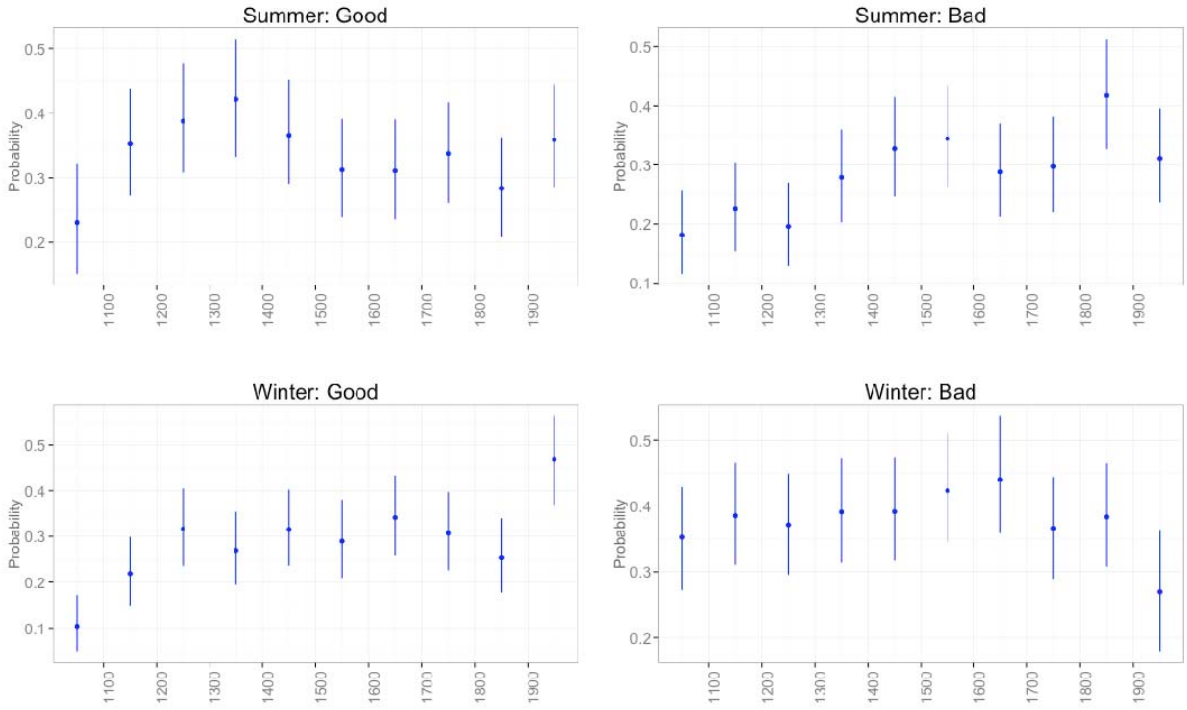
The second difficulty with Büntgen and Hellmann's series arises from the standard climatological practice of smoothing data. In the statistical article, we demonstrate that smoothing a white-noise series (which is what the four climate series that we consider appear to be) leads to the appearance of spurious cycles--a so-called Slutsky effect--as illustrated in the four series of summer temperature in Figure 3, in which each series is smoothed using a thirty-year moving average. Although random, at least before the twentieth century, each series appears to show episodes of unusual cold. The Central European series is particularly relevant to Büntgen and Hellmann; it has a particularly cold episode in the late sixteenth century and other cold spells during the late seventeenth and early nineteenth centuries.

What makes this graph relevant is that, for Büntgen and Hellmann, the most damning evidence against us is the PAGES 2k Consortium reconstruction of European temperature. However, this reconstruction is based on the standard Central European reconstruction that we analyze in the statistical paper and graph-smoothed in Figure 2, with additional tree-ring series from the Pyrenees, Alps, Balkans, and Scandinavia. The LIA episodes of deep cold in the PAGES 2k construction correspond to the spurious dips in our Central European series in Figure 3. [15]

Once again, we emphasize that although the hazards of unthinkingly smoothing weather series is a central theme of our work on the LIA, Büntgen and Hellmann do not mention it once.

[15] PAGES 2k Consortium, "Continental-scale Temperature Variability during the Past Two Millennia," *Nature Geoscience*, VI (2013), 339-346.

Instead, they attempt to refute our findings with what is, in effect, a smoothed version of one of the main series that we analyze and show to be unchanged across the supposed European LIA.

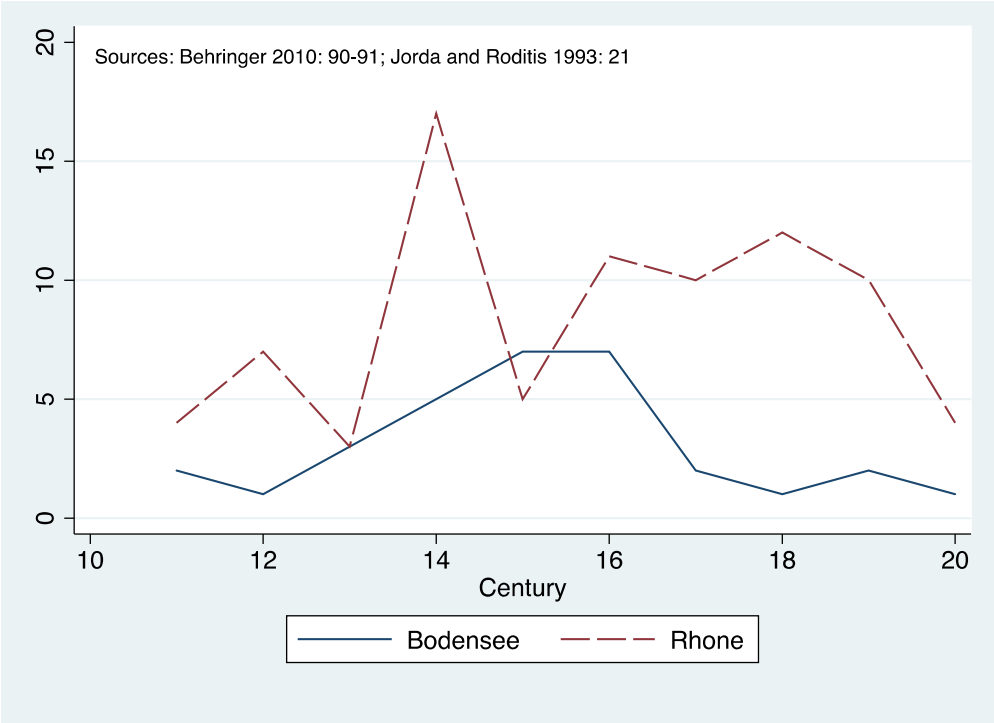


(CAPTION FOR FIGURE 1)

Fig. 1 The Proportion of Good and Bad Summers and Winters in Germany

NOTES Sam White claims this information to be "conspicuously absent from Kelly and Ó Gráda." White's assertion that the reconstruction "clearly suggests that the period between roughly 1400 and 1900, apart from a mild phase in the mid-1700s, was distinctly cooler on average than the centuries before or after" is not immediately evident in these data.

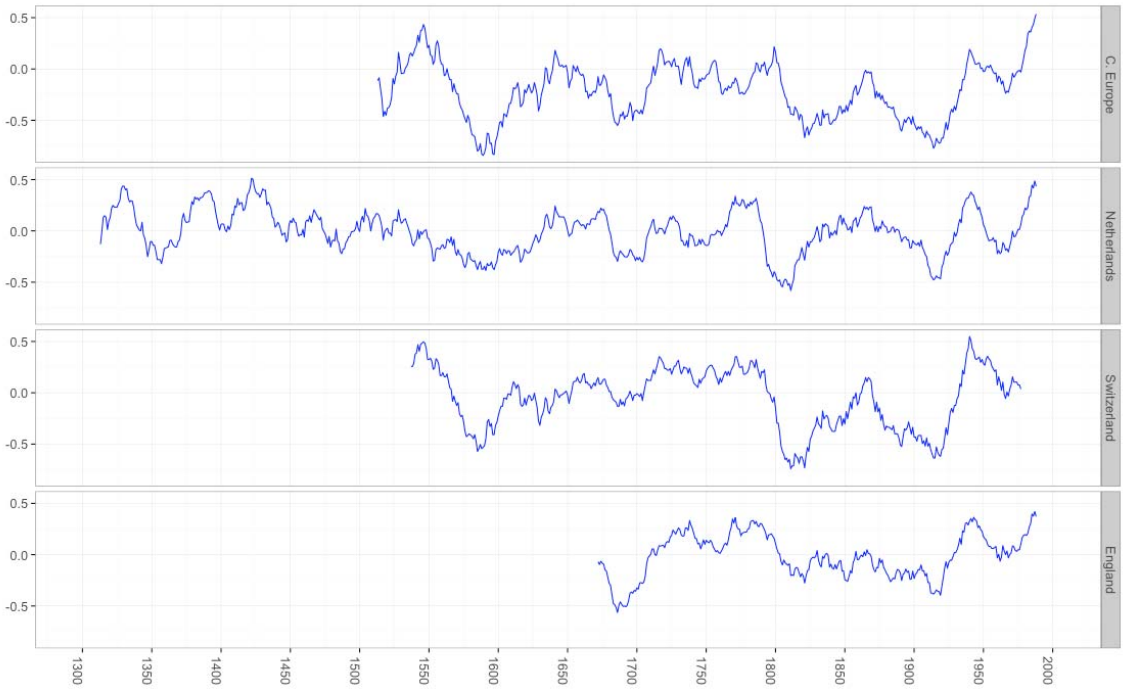
SOURCE This diagram is based on Figure 6 of Morgan Kelly and Cormac Ó Gráda, "Change Points and Temporal Dependence in Reconstructions of Annual Temperature: Did Europe Experience a Little Ice Age?" working paper 2012/10 (University College Dublin Centre for Economic Research, 2012), available at www.ucd.ie/economics/research.



(CAPTION FOR FIGURE 2)

Fig. 2 Frequency of Freezings by Century, 1000 A.D. to 2000 A.D.

SOURCES Wolfgang Behringer, *A Cultural History of Climate* (London, 2010), 90-91; Maurice Jorda and Jean-Christophe Roditis, "Les épisodes de gel du Rhône depuis l'an mil: périodisation, interpretation paléoclimatique," *Méditerranée*, LXXVIII (1993), 21.



(CAPTION FOR FIGURE 3)

Fig. 3 Four Series of Summer Temperatures

NOTES The four temperature series that Morgan Kelly and Cormac Ó Gráda--"Change Points and Temporal Dependence in Reconstructions of Annual Temperature: Did Europe Experience a Little Ice Age?" working paper 2012/10 (University College Dublin Centre for Economic Research, 2012), available at www.ucd.ie/economics/research--demonstrate to be random with a constant mean, appear to show irregular cycles when smoothed with a thirty-year moving average. In particular, the trends in the Central European series closely match the patterns in the PAGES 2k European reconstruction (PAGES 2k Consortium, "Continental-scale Temperature Variability during the Past Two Millennia," *Nature Geoscience*, VI [2013], 339-346).

(END CAPTION)

UCD CENTRE FOR ECONOMIC RESEARCH – RECENT WORKING PAPERS

WP13/01 David Madden: 'Self-Reported and Measured BMI in Ireland: Should We Adjust the Obesity Thresholds?' February 2013
WP13/02 Cormac Ó Gráda: 'Eating People is Wrong: Famine's Darkest Secret?' March 2013
WP13/03 David Madden: 'The Poverty Effects of a "Fat-Tax" in Ireland' March 2013
WP13/04 Cormac Ó Gráda: 'Great Leap, Great Famine' March 2013
WP13/05 David Madden: 'Health and Wealth on the Roller-Coaster: Ireland, 2003-2011' May 2013
WP13/06 Karl Whelan: 'Ireland's Economic Crisis - The Good, the Bad and the Ugly' July 2013
WP13/07 Neil Cummins, Morgan Kelly, and Cormac Ó Gráda: 'Living Standards and Plague in London, 1560–1665' July 2013
WP13/08 Neil Cummins, Morgan Kelly and Cormac Ó Gráda: 'Living Standards and Plague in London, 1560–1665' July 2013
WP13/09 Karl Whelan: 'Sovereign Default and the Euro' July 2013
WP13/10 Orla Doyle, Colm Harmon, James J Heckman, Caitriona Logue and Seong Hyeok Moon: 'Measuring Investment in Human Capital Formation: An Experimental Analysis of Early Life Outcomes' August 2013
WP13/11 Morgan Kelly, Joel Mokyr and Cormac Ó Gráda: 'Precocious Albion: a New Interpretation of the British Industrial Revolution' September 2013
WP13/12 Morgan Kelly, Joel Mokyr and Cormac Ó Gráda: 'Appendix to "Precocious Albion: a New Interpretation of the British Industrial Revolution"' September 2013
WP13/13 David Madden: 'Born to Win? The Role of Circumstances and Luck in Early Childhood Health Inequalities' September 2013
WP13/14 Ronald B Davies: 'Tariff-induced Transfer Pricing and the CCCTB' September 2013
WP13/15 David Madden: 'Winners and Losers on the Roller-Coaster: Ireland, 2003-2011' September 2013
WP13/16 Sarah Parlane and Ying-Yi Tsai: 'Optimal Contract Orders and Relationship-Specific Investments in Vertical Organizations' October 2013
WP13/17 Olivier Bargain, Eliane El Badaoui, Prudence Kwenda, Eric Strobl and Frank Walsh: 'The Formal Sector Wage Premium and Firm Size for Self-employed Workers' October 2013
WP13/18 Kevin Denny and Cormac Ó Gráda 'Irish Attitudes to Immigration During and After the Boom' December 2013
WP13/19 Cormac Ó Gráda ''Because She Never Let Them In': Irish Immigration a Century Ago and Today' December 2013
WP14/01 Matthew T Cole and Ronald B Davies: 'Foreign Bidders Going Once, Going Twice... Protection in Government Procurement Auctions' February 2014
WP14/02 Eibhlin Hudson, David Madden and Irene Mosca: 'A Formal Investigation of Inequalities in Health Behaviours after age 50 on the Island of Ireland' February 2014
WP14/03 Cormac Ó Gráda: 'Fame e Capitale Umano in Inghilterra prima della Rivoluzione Industriale (Hunger and Human Capital in England before the Industrial Revolution)' February 2014
WP14/04 Martin D O'Brien and Karl Whelan: 'Changes in Bank Leverage: Evidence from US Bank Holding Companies' March 2014
WP14/05 Sandra E Black, Paul J Devereux and Kjell G Salvanes: 'Does Grief Transfer across Generations? - In-Utero Deaths and Child Outcomes' March 2014