

When Beer is Safer than Water: Beer Availability and Mortality from Waterborne Illnesses

Francisca M. Antman and James M. Flynn*

University of Colorado Boulder

February 9, 2023

ABSTRACT

We investigate the impact of beer on mortality during the Industrial Revolution in 18th century England. Due to the brewing process, beer represented an improvement over available water sources during this period prior to the widespread understanding of the link between water quality and human health. Using a wide range of identification strategies to derive measures of beer scarcity driven by tax increases, weather events, and soil quality, we show that beer scarcity was associated with higher mortality, especially in the summer months when mortality was more likely to be driven by waterborne illnesses related to contaminated drinking water. We also leverage variation in inherent water quality across parishes using two proxies for water quality to show that beer scarcity resulted in greater deaths in areas with worse water quality. Together, the evidence supports the hypothesis that beer had a major impact on human health during this important period in economic development.

JEL codes: N33, I15, Q25

Keywords: Beer; water quality; mortality; Industrial Revolution

*We thank Brian Beach, Trevon Logan, and participants at the Economic History Association and European Economic Association annual meetings for helpful comments.

1. Introduction

The critical importance of access to clean water for human health and economic development has been underscored in policy circles (UN General Assembly (2015)) and economic research alike (Kremer et al. (2011); Galiani et al. (2005); Devoto et al. (2012); Ashraf et al. (2021)). However, much less attention has been paid to alternatives to drinking water, which may have contributed to human health long before the availability of modern water purification technologies, and thus to the economic development of the world as we know it today. In areas of the world where widespread adoption of water improvement technologies remain out of reach, much can still be learned from this historical experience. This paper provides the first quantitative estimates into one well-known water alternative that may have ultimately proven to be the most impactful for economic development—beer during the Industrial Revolution in England.

Although beer in the present day is regarded primarily as a beverage that would be worse for health than water, several features of both beer and water available during this historical period suggest the opposite was likely to be true. First, brewing beer would have required boiling the water, which would kill many of the dangerous pathogens that could be found in contaminated drinking water. As Bamforth (2004) puts it, ‘the boiling and the hopping were inadvertently water purification techniques’ which made beer safer than water in 17th century Great Britain. Second, the fermentation process which resulted in alcohol may have added antiseptic qualities to the beverage as well (Standage (2006), Ingram and Buttke (1985)). Homan (2004) notes that “because the alcohol killed many detrimental microorganisms, it was safer to drink than water” in the ancient near-east.¹ This property of beer could thus benefit drinkers even if some contaminated water was added to it as beer drinkers could have been protected due to the alcohol content in their stomachs.² Third, beer in this period, which was sometimes re-

¹Similarly, when describing how beer protected drinkers during the London cholera epidemic, Glaeser (2012) notes that “nearby ale imbibers remained healthy; alcohol’s ability to kill waterborne bacteria had long helped city dwellers avoid illness.”

²Sheth et al. (1988) ran an experiment where they added Salmonella, Shigella, and enterotoxigenic *Escherichia coli* to different beverages and monitored survival of the pathogens. Fewer of the pathogens survived in beer than in water or milk. Observational studies have also shown that alcohol drinkers appear to be less vulnerable to various bacteria and viruses spread by contaminated water, e.g., *Helicobacter pylori* (Brenner et al. (1999)), Hepatitis A (Desenclos et al. (1992)), and Salmonella (Bellido-Blasco et al. (2002)).

ferred to as “small beer,” was generally much weaker than it is today, and thus would have been closer to purified water. Accum (1820) found that small beer in late 18th and early 19th century England averaged just 0.75% alcohol by volume, a fraction of the content of the beers of today. While this may have reduced the potential antiseptic qualities of the beer, it also meant that beer in this period was far less harmful to the liver. Taken together, these facts suggest that beer in this period had all of the benefits of purified water with far fewer of the health risks associated with beer consumption today.

In contrast, the quality of plain water in this period, before the establishment of modern sanitation infrastructure and water purification technologies, would have been much more likely to be contaminated by sewage and pathogens, unknowingly contributing to cholera and typhoid outbreaks which were mistakenly thought to be caused by miasmas (Johnson (2006)) until John Snow’s famous discovery that contaminated water from the Broad Street pump in London was behind the spread of cholera in the 1840s (Snow (1855)). Thus, even though people did not recognize beer as a healthful choice, drinking beer would have been an unintentional improvement in beverage over regular water, and thus may have contributed to improvements in human health and economic development over the period we investigate.

While beer has a long history in England that pre-dates the Industrial Revolution (Clark (1998)), to gauge the impact of beer as an alternative beverage we focus instead on limits to the availability of beer during a critical time period for economic development, and examine its impacts on mortality. This approach allows us to make use of several key pieces of data, including a malt price series and tax hike which effectively limited the availability of beer. We also incorporate data on rainfall which would have affected barley production, a necessary ingredient into the production of beer. Thus, we leverage weather shocks which would also have resulted in the relative scarcity of beer. In additional specifications, we make use of information on soil type, which would have affected whether or not barley was grown in a region. This allows us to compare areas in which barley, and thus beer, would have been more readily available to areas in which it was relatively scarce. Following Antman (2022), we also compare areas where water quality was inherently worse to areas where it was inherently better based on two alternative geographic measures and, as expected, observe more severe impacts of

beer scarcity on mortality in areas with worse water quality.

To address concerns that our identification strategy may be picking up the effects of food scarcity, we show that the seasonality of these mortality events matches the summer months, when waterborne mortality crises were at their peak, and not winter months, when deaths from starvation were more likely to occur. Event studies showing mortality rates in parishes with low and high water quality before and after the malt tax increase show larger increases in mortality rates in low water quality parishes after beer became more expensive. These graphs are consistent with the proposed mechanism, and show no evidence of pre-existing trends in mortality prior to the malt tax increase, suggesting our results are robust to concerns over parallel trends. To address the possibility that alternative explanations might be driving our results, we also control for regional wages and tea imports to rule out correlated effects driven by the availability of tea which would have been another improvement over drinking water (Antman (2022)). Through all these approaches, we find evidence that the relative scarcity of beer resulted in higher mortality, and thus consistent with the hypothesis that beer played a critical role in protecting human health during this important period of economic development.

This paper connects closely with the literature examining the importance of drinking water sources for human health and economic development. However, quantifying the role of water in shaping economic development is complicated by the fact that its importance is so well-known, thus raising the specter of selection bias in many estimated treatment effects. While explicitly randomized controlled trials may be feasible to evaluate short-term impacts in some settings (Kremer et al. (2011)), costly barriers to adopting water quality interventions often remain (Zinn et al. (2018)) and thus raise questions about their long-term impacts. Historical evaluations of large-scale water interventions in the U.S. present an alternative empirical approach (Alsan and Goldin (2019); Beach et al. (2016); Ferrie and Troesken (2008); Cutler and Miller (2005); Troesken (2004)), however, the simple fact that they were implemented as public health interventions suggest that the link between water and health was already well established by the period of time in which they were undertaken, thus again raising the issue of potential endogeneity and selection bias. This paper provides an important research alternative, since the period precedes the modern understanding of the germ theory of disease

and the widespread understanding of the link between water and human health (Johnson (2006)). As such, it connects closely with Antman (2022) which shows the impact of tea on mortality in England. We follow a similar approach, but in examining the impact of beer, shed light on an important alternative to water with a long history in England that helped pave the way for economic development. While we are not the first ones to hypothesize the impact of beer on economic development (see for example Standage (2006)), to our knowledge this paper represents the first quantitative analysis.

The paper proceeds as follows. Section 2 provides background information on beer production in England and mortality rates in England that underlie our identification strategy. Section 3 presents the data used in the analysis. Section 4 presents the methodology and results. Section 5 concludes.

2. Background

Our multiple identification strategies rely on several important facts about beer production and deaths related to waterborne diseases which we discuss here.

2.1. Beer Production

First, beer production is largely dependent on the availability of malt, one of the four main ingredients in beer.³ According to Clark (1998), malt made up approximately two-thirds of the cost of beer production through the 19th century. Therefore, when malt is abundant and cheap, beer tends to be as well, and vice versa. Second, as malt is made of barley, malt production depends almost entirely on the yield of the barley crop. This means that the availability of beer for consumption is correlated with the suitability of a year's weather for growing barley. During overly wet growing seasons, barley yields decline, leading to less malt and less beer being produced.

Third, barley grows best in fertile loam soil, which is most common in those characterized as gley soils.⁴ Nearly half (48.4%) of parishes in the malt-producing hub East Anglia⁵ are classified as having gley soil, while only 16.9% of parishes

³The others being water, yeast, and hops.

⁴[https://www.landis.org.uk/downloads/downloads/Soil classification.pdf](https://www.landis.org.uk/downloads/downloads/Soil%20classification.pdf).

⁵This region includes the counties of Norfolk, Suffolk and Cambridgeshire in the east of England.

outside of East Anglia have gley soil. This means that beer would be more commonly available in areas with gley soils. Before railroads became ubiquitous in the United Kingdom in the middle of the 19th century, it was difficult and expensive to transport barley long distances. Though we do not have data on the geographic variation in prices, it seems reasonable to believe that this would cause beer to be cheaper and more abundant in areas where barley was grown. Subsequently, because our causal mechanism relies on people substituting water consumption with beer consumption, this is likely most common in areas with gley soil, where beer was relatively more abundant in the first place. Thus, these areas should experience a relatively bigger increase in deaths from waterborne illnesses whenever there is a negative shock in beer availability. Fourth, the quality of available water is an important determinant of the likelihood of death from a waterborne illness. As argued in Antman (2022), parishes with few nearby sources of running water and parishes at relatively lower elevation have worse inherent water quality, thus they would have been more likely to experience a greater increase in deaths whenever beer became scarce.

2.2. *Seasonality of Waterborne Illnesses*

While starvation deaths from a poor crop yield occur throughout the year and may be especially pronounced during winter months, waterborne illness deaths are concentrated in the summer. This is because gram-negative bacteria, which include many of most common causes of illness from drinking contaminated water, survive best during the warm summer months (Schwab et al. (2014), Eber et al. (2011), Richet (2012)). Specifically, studies have demonstrated summertime peaks for *E. coli* (Al-Hasan et al. (2009), Freeman et al. (2009)), *Salmonella* (Yun et al. (2016), Saad et al. (2018)), *Giardia* (Tangtrongsup et al. (2020), Ali-Shtayeh et al. (1989)), and the bacteria which cause Dysentery (Naous et al. (2013), Chen et al. (2019), Lee et al. (2017)), as well as many others.⁶

To illustrate this pattern, Figure 1 compares average monthly mortality rates across England before and during the 1831-1832 cholera pandemic (Chan et al. (2013), Burrell and Gill (2005)) and around the Pan-European famine which affected much of Western Europe, including Britain, from 1585-1587 and 1590-1598.

⁶Summer peaks have also been demonstrated for *Campylobacter* (Strachan et al. (2013)), *Cyclosporiasis* (Casillas et al. (2018), Kaminsky et al. (2016)), *Leptospirosis* (Ward (2002)) and *Vibrio* (Mahmud et al. (2008)).

The left panel of Figure 1 shows that from 1800-1830, average mortality peaked in the winter months of January-April before declining to a trough in the summer months of July-September.⁷ Similarly, in 1831-1832, during the cholera pandemic, there is a peak in the winter months, and deaths begin to decline in the spring-time. In contrast, however, deaths rise once again in the summer months of July-September during the cholera pandemic, while they reach their lowest points in the non-cholera years. The right panel of Figure 1 shows average monthly mortality from 1580-1600 for famine years (1585-1587, 1590-1598) versus non-famine years (1580-1584, 1588-1589, 1599-1600).⁸ Average mortality is higher in famine years across the board, not just during one particular season. If anything, deaths appear to be most pronounced in December, March and April. These trends allow us to separate the impacts of starvation-related deaths from waterborne illness deaths by looking for clusters in the summer months only.

2.3. *The Malt Excise Tax*

In the seventeenth century the British Crown began looking for ways to tax the growing revenues of the major brewers. This would be difficult because outside of London the majority of beer was made in small alehouses and was difficult to track. In 1620, King James I came up with the solution of banning all small-scale victuallers (those licensed to sell alcohol), forcing them to purchase beer from the larger brewers who could be more easily monitored. In response, the small country brewers agreed to pay the same levy that London brewers paid on malt. This would eventually be scrapped by Parliament in 1624 (Cornell (2003)), but a malt excise tax would return later in the 17th century and would be collected until 1880.

The tax was reinstated in 1697 at .5625 schillings per bushel of malt as part of a shift from taxing land and customs towards excise taxes, which would continue throughout the 18th century (Nye (2007)). This was combined with a number of regulations on every stage of the malting process in an effort to prevent tax avoidance (Mathias (1959)). The brewing industry tacitly agreed to the tax in exchange for protection from competition from imported substitutes like French wines. Increasing concentration in the brewing industry during this period both made it easier to monitor and collect the taxes and enabled brewers to pass on the majority

⁷A similar pattern emerges if we focus on a shorter period from 1820-1830.

⁸These crises are documented in Alfani and Gráda (2018) and McNicoll (2018).

of the tax onto consumers, who had little in the way of recourse (Nye (2007)). The tax would remain at .5625 schillings per bushel until it was raised to .75 schillings per bushel in 1760, before a large increase to about 1.354 schillings per bushel in 1780.

One of the reasons why it was advantageous to tax malt as opposed to beer is that it makes the tax more difficult to avoid. Homebrewing is a relatively simple exercise with finished malt, but making one's own malt to use in brewing is much more difficult. By extracting the tax earlier in the production process, this made it more challenging for the everyday homebrewer to circumvent the tax by making beer at home and not reporting it to the tax authorities. This partially explains why the malt tax helped concentrate the malting and brewing industries by preventing households from brewing their own beer for everyday use and also contributed to the rising cost of beer (Cobbett (1833)).

3. Data

We combine data from several sources in order to estimate the impact of beer availability on deaths from waterborne illness in 18th and 19th century England. As part of our multiple identification strategies, we exploit two plausibly exogenous sources of variation in the availability of beer. First, we use a change to the British Malt Tax which occurred in 1780 (Stopes (1885)). If higher malt taxes lead to beer becoming more scarce in certain years, we might expect people to substitute from drinking beer to drinking water, leading to increased deaths due to waterborne illnesses, especially in areas where water quality is lower. Our other source of variation in the availability of beer is due to weather. We use data from Briffa et al. (2009) which identifies historical weather patterns using the Palmer Draught Severity Index (PDSI). These data are available for London from 1697-2000. The PDSI is a measure of regional moisture availability that has been used extensively to study historical wet and dry spells. The PDSI classifies each month on a scale from -4 (extremely dry) to 4 (extremely wet). As extremely wet growing seasons are detrimental to barley yield, we can expect beer to be more scarce in years with a higher PDSI during the barley growing months.

We construct mortality rates and other parish-level characteristics using Wrigley and Schofield (2003)'s collection of records on burials, baptisms, and marriages.

These records include data on 404 parishes covering the years 1538-1849. Using these data, we follow the methodology from Wachter (1998) to impute population counts for each parish-year combination as a weighted average of previous years' burials, baptisms, and marriages.

We proxy for water quality in multiple ways following Antman (2022). First, we use the average elevation of each parish, constructed by combining Shuttle Radar Topography images (Jarvis et al. (2008)) with historical parish boundaries (Southall and Burton (2004)). Our reasoning behind using this measure is that all else equal, the higher elevation parishes are likely to have cleaner water because they will be less contaminated by runoff from their lower-elevation neighbors. Second, we use the number of running water sources available in an area, as given by the main rivers within three kilometers of the parish, which was calculated using data from the United Kingdom Environment Agency Statutory Main River Map of England overlaid on a map of historical parish boundaries (Burton et al. (2004); Southall and Burton (2004)). Our reason for using this measure is that having greater natural sources of running water would have been critically important for obtaining clean water during this period before water infrastructure projects became commonplace. Of course, both of these geographic measures may be correlated with economic development independently, and thus, we control for parish fixed effects in all specifications and emphasize that we are focused only on the impact of the water quality measures on mortality through their interaction with measures capturing the availability of beer.

4. Methods and Results

4.1. Malt Tax Increase of 1780

We begin by analyzing the effects of a large increase in the malt tax, which occurred in 1780. Prior to 1780, the malt tax had not been raised since 1760 and was only .75 schillings per bushel, which represented about 20% of the 1779 selling price of brown malt (28.83 schillings according to Mathias (1959)). In 1780, the malt tax nearly doubled to about 1.354 schillings per bushel. At the time, this represented the largest hike in the tax since its inception in 1697. By focusing on what happened to summer and winter death rates in the years surrounding this large increase, we can gain a better understanding of the impact of beer on public health

since waterborne diseases were more prevalent in the summer. Of particular interest is what happens in parishes with better versus worse water quality when beer becomes more scarce. If the tax caused individuals to substitute from beer to water, we would expect to see relative increases in summer deaths in parishes with poor water quality. We look into this by running models of the following form:

$$\begin{aligned}
 SmrDths_{it} = & \beta_1 LoWaterQual_i * Post_t + \beta_2 HiWaterQual_i * Post_t + \\
 & X_{it}\beta_3 + \mu_i + \delta_t + \psi_{it} + \epsilon_{it}
 \end{aligned}
 \tag{1}$$

where $SmrDths_{it}$ is the log of burials in parish i in the summer of year t , $LoWaterQual_i$ is an indicator for whether the parish is below the 25th percentile in the measure of water quality, $HiWaterQual_i$ is an indicator for being above the 75th percentile in water quality, and $Post_t$ is an indicator for being after the 1780 malt tax increase. We control for the impact of rising tea imports around this period by interacting national tea imports with the indicators for high and low water quality and including them in X_{it} , along with the log of the estimated parish population, regional wages by quinquennia from Clark (2001), and the number of deaths occurring in the winter. The latter should account for factors which influence parish death rates throughout the year. Additionally, we include parish fixed effects, μ_i , year fixed effects, δ_t , and parish-specific time-trends, ψ_{it} , in all specifications to ensure our estimates of interest are purged of any spurious correlations that affect specific parishes across time, specific years across parishes, or which may be growing over time at the parish level. We limit our sample to the years immediately surrounding the malt tax increase, i.e., $t = 1770, 1771, \dots, 1790$. The parameters of interest, β_1 and β_2 , therefore measure how well the low water quality and high water quality parishes did in comparison to the parishes with average levels of water quality in response to the tax increase. If better water leads to fewer deaths, we would expect summer deaths in the low water quality parishes to increase more in response to the malt tax relative to the change in deaths in higher water quality parishes. We would therefore expect a positive β_1 and a negative β_2 . Results from estimating this model using the number of running water sources available (main rivers) as the measure of water quality, and, subsequently, elevation, are displayed in Table 1.

Column 1 of the top panel of Table 1 shows the results for parishes with few available water sources compared with all others. In the years following the malt tax increase, these parishes see a 16.5 log points (about 18%) rise in the summer death rate, with a p-value of .006.⁹ Conversely, column 2 shows that parishes with the most available water sources, which should be more protected from the dangers of contaminated water, see their summer death rates fall by 14.6 log points (about 16%) relative to all other parishes (p-value = .006). When both interaction terms are included in the model, we see that the difference between the two coefficients suggests that the summer death rate in low water quality parishes increases by 22.2 log points (about 25%) relative to high water quality parishes, with a p-value on the equality of the two coefficients of .001. Columns 4-6 replicate columns 1-3 with the ratio of summer versus winter deaths on the left-hand side, and the economic inference is similar. After the malt tax increase went into effect, summer deaths in low water quality areas rose relative to winter deaths, while high water quality parishes did comparatively better than medium and low water quality parishes, potentially because switching from beer to water consumption is less costly when the water quality is better. Appendix Table 1 displays a falsification version of this model, which replaces the summer death rate with the winter death rate on the left hand side and replicates columns 1-3 of Table 1. All of the interaction terms in Appendix Table 1 are insignificant and close to zero, suggesting that the changes which took place in the years following the increase in the malt tax mainly affected the summer death rates, which is consistent with our hypothesis.

The middle panel of Table 1 displays results replacing the number of nearby water sources with elevation as a measure of water quality. Results are similar qualitatively, with low water quality parishes seeing much higher summer death rates. In this case, being in the bottom quartile of elevation was associated with a 12.3 log point increase in the summer death rate, while being in the top quartile of water sources was associated with a similar decrease in summer deaths. The difference between the coefficients in column three suggests that low elevation parishes saw summer death rates rise by 18.6 log points relative to high elevation parishes (p-value = .018). Columns 4-6 again replicate columns 1-3, switching

⁹Percentage changes are calculated using the following transformation: $[\exp^{(.01x)}-1] * 100$, where x is the log point difference.

summer deaths with the ratio between summer and winter deaths on the left-hand side. Again, the results are qualitatively similar, though the p-value on the difference between the two coefficients when both are included is now .146. There is little correlation between the two measures of water quality (correlation coefficient of .0487), so the similarity in results is not driven by the same parishes being identified in both samples. Appendix Table 2 displays the falsification test, switching summer and winter deaths on the left hand side. Once again, all of the coefficients are much smaller in magnitude and insignificant, indicating that the increased death rates which occurred in low water quality parishes after the malt tax was increased mainly took place during the summer months.

Finally, the bottom panel of Table 1 displays results on the intersection of the two water quality measures. *Low * Low * Post* measures the change in summer mortality for the 31 parishes with both low elevation and a low number of water sources, while *High * High * Post* tracks the 30 parishes with high elevation and a high number of water sources, with both estimates measured relative to the 374-375 other parishes in the sample. If our hypothesis is correct, parishes which have poor (high) water quality on both metrics should be especially exposed (protected). The results are consistent with this story, as all of the coefficients are larger in magnitude and significance than their counterparts, suggesting that the parishes with the worst water quality were especially exposed to this increase in the malt tax.

4.2. Soil Suitability

Focusing instead on areas where beer production was most common, and therefore most vulnerable to malt tax increases, we run similar models to see whether parishes with gley soil suffered a relatively bigger increase in summer deaths in response to the increase in the malt tax. We do this by estimating models of the following form:

$$SmrDths_{it} = \beta_1 GleySoil_i * Post_t + X_{it}\beta_2 + \mu_i + \delta_t + \psi_{it} + \epsilon_{it} \quad (2)$$

where $GleySoil_i$ is an indicator for parish i having gley soil and all else is as described below equation (1). Results from this model are displayed in Table 2. In columns 1-3, parishes with gley soil had summer death rates which increased by about 18 log points after the malt tax was implemented relative to parishes without

gley soil. Appendix Table 3 displays the falsification test which switches summer and winter deaths on the left hand side. The effects of interest are all less than one third as large as in the main specification and are all insignificant. Taken together, the results from this section relying on soil suitability show strong support for our hypothesized mechanism operating through the availability of beer. Moreover, in order for our hypothesis to be false, there would have to be some other factor which simultaneously precipitated an increase in summer deaths in low elevation parishes, parishes with few water sources, and parishes with gley soil, immediately after the increase in the malt tax in 1780. While impossible to completely rule out, such a factor seems unlikely to exist.

4.3. Event Study

Recently, difference-in-differences estimation models with staggered treatment timing have come under scrutiny for a variety of reasons (Goodman-Bacon (2021), Sun and Abraham (2021), Callaway and Sant’Anna (2021)). These concerns do not apply to our setting which involves a single treatment whose timing is constant across parishes. Nevertheless, some may be concerned that pre-existing trends may be obfuscating our estimates of the treatment effect. To address, this we must provide support for the equal counterfactual trends assumption that is inherent to the difference-in-differences study setting.

For example, some might be concerned that summer deaths may have been decreasing in high water quality parishes relative to low water quality parishes throughout the sample period, and that the results from above may be driven by that relationship. Since the difference-in-differences estimator is essentially comparing changes in conditional means across two periods, such a trend would wrongfully be picked up as a treatment effect. One way to deal with this issue is by using event-study designs which allow the treatment effect to vary in each year. This allows for the inclusion of pre-treatment indicators, which can identify any problematic pre-treatment trends and demonstrate whether the two groups were on similar trajectories before the treatment went into effect. To this end, we estimate models of the following form:

$$SmrDths_{it} = \sum_{k=-5}^6 \theta_k(ParishType_i * Year_{t+k}) + X_{it}\beta + \mu_i + \delta_t + \psi_it + \epsilon_{it} \quad (3)$$

where the only difference from equation (2) is that now we estimate separate treatment effects for five years before and six years after the malt tax increase went into effect. We estimate models of this form in multiple regressions where we replace $ParishType_i$ with separate indicators for low water source parishes, low elevation parishes, and parishes with gley soil. Ideally, the coefficients should all be close to zero and insignificant in the periods before the intervention. Then, shortly after the malt tax was raised in 1780, we should see relative increases in summer deaths in each specification.

Figure 2 displays these estimates for all four groups. The top left graph displays the estimates for the parishes with few nearby water sources. From 1775-1778, the coefficients are all small in magnitude and insignificant, with the smallest p-value of .66. A test on the joint significance of the 1775-1778 coefficients yields a p-value of .93. There is a slight uptick in 1780, but then a large and significant increase of 20.0 log points in 1781. After that, all the subsequent coefficients are positive and remain between .04 and .25. A test on the joint significance of the 1781-1784 coefficients yields a p-value of .03. The top right graph displays estimates on the low elevation parishes, and the results here are perhaps the weakest of the four. Still, however, the coefficients are around zero and all insignificant in the pre-period, with increases in summer mortality directly after the tax went into effect in 1780. A test for joint significance on the 1775-1778 coefficients yields a p-value of .42, while a test on 1781-1784 yields a p-value of .05.

The bottom left graph repeats this exercise for the parishes with gley soil and the results are similar. There does not appear to be much of a pretrend, though the 1776 coefficient is negative and borderline significant on its own. A test of joint significance on 1775-1778 yields a p-value of .12. After 1780, the coefficients are all positive and rise up to a peak in 1783 before leveling off and reverting somewhat. A test of joint significance on the 1781-1784 coefficients yields a p-value of .002. Finally, the bottom right graph estimates equation (3) on the parishes which have few water sources, low elevation and gley soil. The results are once again similar, with little evidence of pretrends before 1780 (p-value of .76 for 1775-1778), and then substantial increases in summer mortality for these most-exposed parishes after the increase in the malt tax (p-value of .015 for 1781-1784). Across all four specifications, it is clear that very little was happening in the years leading up to the malt tax hike of 1780, but then large increases in summer mortality occurred

in the parishes which were most exposed to the effect of the tax shortly thereafter.

4.4. Yearly Rainfall Interactions with Water Sources and Soil Type

Finally, we demonstrate that in rainier barley growing seasons, which are less conducive to barley growing, summer deaths rise relative to winter deaths, with these effects concentrated in areas where the most barley is produced and areas where water quality is poorest. This is consistent with our proposed mechanism that decreased availability of beer leads people to substitute drinking beer with drinking water, which leads to an increased risk of contracting a waterborne illness. We do this by estimating models of the following form:

$$SmrDths_{it} = \beta_1 Rain_t * LoWaterQual_i + \beta_2 Rain_t * GleySoil_i + \beta_3 Rain_t * GleySoil_i * LoWaterQual_i + \beta_4 X_{it} + \mu_i + \delta_t + \psi_{it} + \epsilon_{it} \quad (4)$$

where $Rain_t$ represents the Palmer Drought Severity Index, a measure of historical rainfall, for London during the main barley-growing months of February through May in year t . The PDSI ranges from about negative four (extremely dry) to positive 4 (extremely wet). Since overly wet barley growing seasons are bad for barley production, large positive values of the PDSI will lead to a decreased crop yield. Because our rain data is for London, the sample is limited to the parishes which surround the London metropolitan area.¹⁰ Consequently, we use only the number of water sources as a measure of water quality in this specification because there is substantially less variation in elevation across these parishes. The three interaction terms, $Rain_t * LowSources$, $Rain_t * GleySoil$, and $Rain * GleySoil * LowSources$, measure whether rainier seasons are more impactful to summer death rates in areas with few nearby water sources and in areas with gley soil, where barley production is most common.¹¹ If rainy barley growing seasons lead people to consume more unsafe drinking water, we would expect all three coefficients to be positive. The remaining variables in equation (4) are the same as specified in our previous models. Results from this specification are reported in Table 3.

¹⁰These include the parishes of Buckinghamshire, Surrey, Berkshire, Essex, Herefordshire, Kent, Middlesex, Bedfordshire, Cambridgeshire, Huntingdonshire, Hampshire, Norfolk, Oxfordshire, Suffolk and Sussex.

¹¹It should be noted that the interaction term $GleySoil * LowSources$ is accounted for by the parish fixed effects and therefore not added to equation (4).

For comparison, the first three columns of Table 3 build up to the full model in equation (4) by progressively adding interaction terms. In column (1), the interaction term measuring the effect of rainier barley growing seasons on parishes with few nearby water sources is positive and significant, indicating that summer deaths rise following particularly rainy barley growing seasons. Column (2) replaces the *Rain * Sources* interaction with *Rain * GleySoil* and demonstrates that rainy barley-growing seasons lead to more summer deaths in areas where beer is most abundant and the population is more accustomed to the availability of beer, even controlling for the number of deaths occurring in the winter months. Column (3) includes both interaction terms to address concerns that the measures may simply be highly correlated, and thus positive and significant. However, even when included separately, both coefficients of interest remain positive and significant at the 0.1 significance level. Column (4) adds a triple-interaction term, *Rain * Gley * Sources*, which measures the effect of rainy barley-growing seasons on parishes with gley soil and few nearby water sources. When this is included, the two interaction terms lose significance and are close to zero, but the triple-difference is positive and significant at 5%, suggesting that parishes with lower water quality and gley soil are particularly vulnerable to beer scarcity driven by a low barley yield. Column 5 replaces the log of summer deaths on the left-hand side with the ratio between summer and winter deaths and the effect is still positive and significant, indicating that these effects are acutely felt during the summer months and not year-round, as our hypothesis would predict.

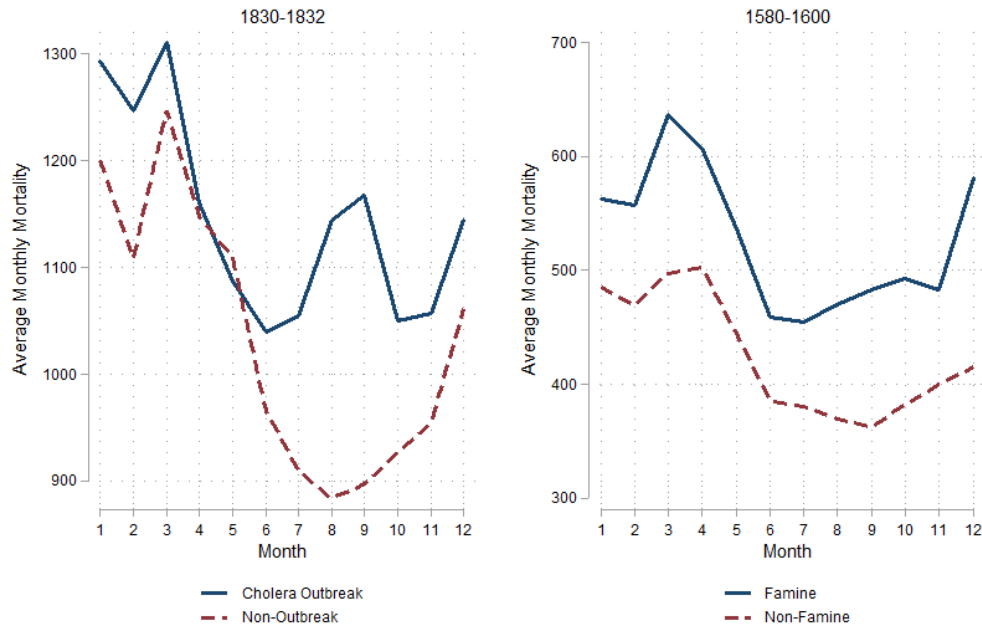
5. Conclusion

Through a panoply of evidence and several identification strategies, this paper provides the first quantitative evidence of the importance of beer to human health during the Industrial Revolution in England. As demonstrated here, the relative scarcity of beer—whether driven by a tax hike or a poor crop yield due to excessive rainfall—contributed to rising deaths in England. The estimates showing disparate impacts across areas which varied in their inherent water quality, using two different proxies for water quality, also suggest that the root cause of the variation in mortality associated with beer was indeed driven by water quality as opposed to some other explanation. The additional evidence leveraging variation in parish re-

liance on beer due to its relative abundance as driven by variation in soil suitability, also points to the primacy of beer in explaining the patterns observed. Moreover, the seasonal pattern of deaths suggest these mortality events were not driven by starvation, but by waterborne diseases which had larger impacts when beer was relatively scarce.

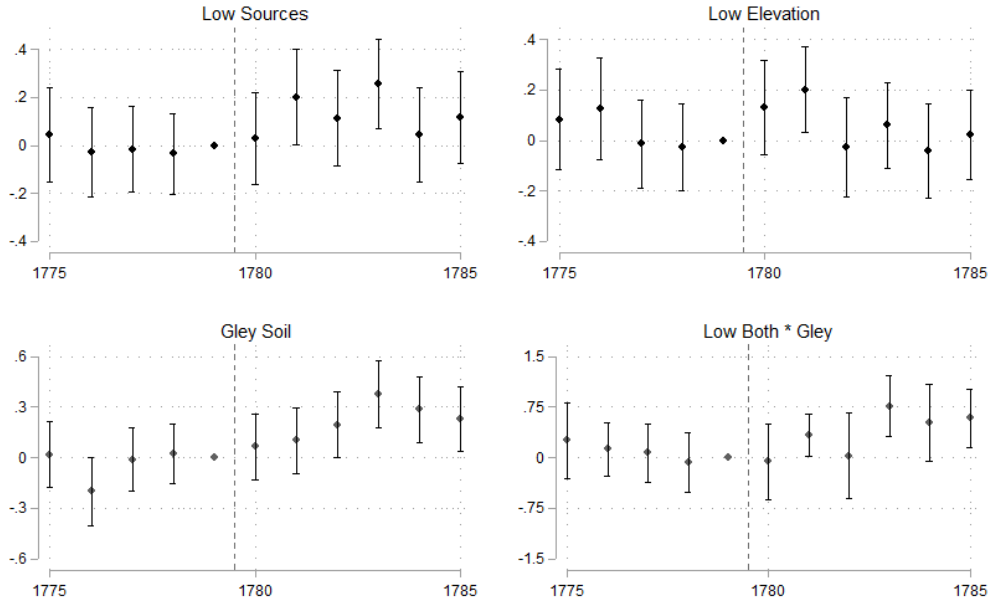
While this research highlights the importance of alternative beverages to human history, it also underscores the importance of access to clean water for human health and economic development today. In areas of the world where widespread adoption of water improvement technologies remain out of reach, much can still be learned from this historical experience. In particular, harnessing culture and custom to drive the adoption of an alternative beverage or health technology may ultimately prove to be most consequential for economic development.

Figure 1 – Comparing Monthly Mortality in England Around Crises Caused by Waterborne Illness versus Famine.



Note: This figure displays monthly average mortality during and around two crises in English history. The left graph displays mortality before and during the 1831-32 cholera outbreak. The solid line displays monthly mortality during the outbreak, while the dashed line displays average monthly mortality in the 30 years leading up to it (1800-1830). The graph on the right shows monthly English mortality around the Pan-European famine of the 1580s and 1590s. 1580-1584, 1588-1589, and 1599-1600 were the famine years, and monthly mortality in these years is indicated by the solid line. Monthly mortality in non-famine years (1585-1586, 1590-1598) is indicated by the dashed line.

Figure 2 — Event-Study Estimates of the Effect of the 1780 Malt Tax Increase on Summertime Mortality in Parishes with Few Water Sources, Low Elevation, and Gley Soil.



Note: This figure displays event-study estimates comparing the summer death rate in parishes that are more exposed to the malt tax increase. The top left graph displays estimates for parishes with few nearby water sources, the top right graph displays estimates for parishes with low elevation, the bottom left graph displays estimates for parishes which have gley soil, and the bottom right displays estimates for parishes with low water sources, low elevation and gley soil.

Table 1 — The Effect of the 1780 Malt Tax Increase on Summertime Mortality in Parishes with Varying Levels of Inherent Water Quality.

	(1)	(2)	(3)	(4)	(5)	(6)
	Smr Dths	Smr Dths	Smr Dths	Ratio	Ratio	Ratio
Low Sources * Post	0.165*** (0.0601)		0.129* (0.0660)	0.261** (0.106)		0.244** (0.118)
High Sources * Post		-0.146*** (0.0532)	-0.0929 (0.0585)		-0.145* (0.0862)	-0.0437 (0.0979)
Difference			0.222			.2877
P-value			.001			.010
Low Elevation * Post	0.123* (0.0651)		0.0930 (0.0680)	0.253** (0.118)		0.273** (0.121)
High Elevation * Post		-0.122** (0.0598)	-0.0931 (0.0624)		-0.0222 (0.110)	0.0624 (0.113)
Difference			0.186			.211
P-value			.0175			.146
Low * Low * Post	0.248** (0.115)		0.229** (0.116)	0.491*** (0.183)		0.475** (0.184)
High * High * Post		-0.284*** (0.0761)	-0.269*** (0.0763)		-0.261** (0.125)	-0.228* (0.126)
Difference			0.497			.703
P-value			.0002			.0009
Observations	7448	7448	7448	7991	7991	7991

Note: This table compares outcomes before and after the 1780 increase in the malt tax for parishes above the 75th percentile and below the 25th percentile in water quality (high and low water quality, respectively), relative to parishes in the 25th-75th percentile range of water quality. The top panel uses the number of available water sources as the measure of water quality, the middle panel uses the elevation of the parish, while the bottom panel estimates the model on the intersection of the two measures of water quality. The first two columns use the log of the summer death rate as the dependent variable and estimate the coefficient on high and low water quality parishes separately, before including them in the same regression (column 3). Also in column 3, the difference between the high and low water quality coefficients is calculated and a p-value on the equality of the coefficients is displayed. Columns 4-6 replicate columns 1-3 using the ratio between summer and winter deaths as the dependent variable. In every specification, controls are included for parish population, regional wages, tea imports, parish and year fixed effects as well as a parish linear time trend. In columns 1-3, the log of the number of winter deaths is also included. * $p < 0.10$, ** $p < 0.05$, *** $p < .01$

Table 2 — The Effect of the 1780 Malt Tax Increase on Summertime Mortality in Parishes with Gley Soil.

	(1)	(2)	(3)	(4)
	Smr Dths	Smr Dths	Smr Dths	Ratio
Post - Gley Soil	0.182*** (0.0611)	0.177*** (0.0610)	0.175*** (0.0625)	0.145 (0.108)
Log Population		-0.935*** (0.314)	-1.111*** (0.346)	0.220 (0.488)
Log Wage		0.275 (0.245)	0.319 (0.250)	0.513 (0.369)
Log Tea Imports		0.0617 (0.0826)	0.149* (0.0874)	-0.524*** (0.134)
Winter Deaths			0.0490*** (0.0154)	
Observations	7775	7753	7448	7991

Note: This table compares outcomes before and after the 1780 increase in the malt tax for parishes with gley soil compared to all other counties. Column 1 includes parish and year fixed effects as well as a parish linear time trend. Column 2 adds controls for population, regional wages and tea imports. Column 3 includes the log of winter deaths to control for factors which impact death rates year round, while column 4 replaces the log of summer deaths with the ratio between summer and winter deaths as the dependent variable and drops winter deaths as a control since it is included on the left-hand side. * $p < 0.10$, ** $p < 0.05$, *** $p < .01$

Table 3 – The Effect of Rainy Barley Growing Seasons on Summertime Mortality in Parishes with Few Water Sources and Gley Soil - 1726-1830.

	(1)	(2)	(3)	(4)	(5)
	Smr Dths	Smr Dths	Smr Dths	Smr Dths	Ratio
Rain x LoWaterQual	0.00330** (0.00161)		0.00288* (0.00160)	0.0000660 (0.00174)	-0.000488 (0.00239)
Rain x Gley		0.00372* (0.00195)	0.00328* (0.00192)	-0.00121 (0.00279)	-0.00499 (0.00396)
Rain x Gley x LoWaterQual				0.00922** (0.00368)	0.0128** (0.00511)
Observations	10315	10315	10315	10315	11125

Note: This table displays estimates of the effect of rainy barley growing seasons on different types of parishes which are more or less vulnerable to shocks in beer availability. Column 1 measures the impact on parishes with few nearby water sources, while column 2 estimates the impact on parishes with gley soil, which would otherwise be able to produce large quantities of barley. Column 3 includes both singular interactions, while column 4 includes the singular interactions and the joint interaction measuring the effect of rainy barley growing seasons on parishes with few water sources and gley soil. Column 5 includes the joint interaction and replaces the log of summer deaths on the left hand side with the ratio between summer and winter deaths. In every specification, controls are included for parish population, regional wages, tea imports, parish and year fixed effects as well as a parish linear time trend. Except in column 5, the number of winter deaths in that parish is also included to control for factors which impact mortality year round. * $p < 0.10$, ** $p < 0.05$, *** $p < .01$.

References

- Accum, Friedrich Christian (1820). *A treatise on adulterations of food, and culinary poisons: Exhibiting the fraudulent sophistications of bread, beer, wine, spiritous liquors, tea, coffee ... and methods of detecting them*. Longman, Hurst.
- Alfani, Guido and Cormac Ó Gráda (2018). “The timing and causes of famines in Europe.” In: *Nature Sustainability* 1, pp. 283–288.
- Ali-Shtayeh, M. S. et al. (1989). “Prevalence and seasonal fluctuations of intestinal parasitic infections in the Nablus area, West Bank of Jordan”. In: *Annals of Tropical Medicine & Parasitology* 83.1, pp. 67–72.
- Alsan, Marcella and Claudia Goldin (2019). “Watersheds in Child Mortality: The Role of Effective Water and Sewerage Infrastructure, 1880–1920”. In: *Journal of Political Economy* 127.2, pp. 586–638.
- Antman, Francisca M. (Jan. 2022). “For Want of a Cup: The Rise of Tea in England and the Impact of Water Quality on Mortality”. In: *The Review of Economics and Statistics*, pp. 1–45. ISSN: 0034-6535.
- Ashraf, Nava et al. (2021). “Water, Health and Wealth: The Impact of Piped Water Outages on Disease Prevalence and Financial Transactions in Zambia”. In: *Economica* 88.351, pp. 755–781.
- Assembly, UN General (2015). *Transforming our world : the 2030 Agenda for Sustainable Development*. Tech. rep.
- Bamforth, Charles W. (2004). *Beer: Health and nutrition*. Blackwell Science.
- Beach, Brian et al. (2016). “Typhoid Fever, Water Quality, and Human Capital Formation”. In: *The Journal of Economic History* 76.1, pp. 41–75.
- Bellido-Blasco, Juan B. et al. (2002). “The Protective Effect of Alcoholic Beverages on the Occurrence of a Salmonella Food-Borne Outbreak”. In: *Epidemiology* 13.2, pp. 228–230. ISSN: 10443983.
- Brenner, Hermann et al. (May 1999). “Alcohol consumption and Helicobacter pylori infection: Results from the German National Health and Nutrition survey”. English (US). In: *Epidemiology* 10.3, pp. 214–218. ISSN: 1044-3983.
- Briffa, K. R., G. van der Schrier, and P. D. Jones (2009). “Wet and dry summers in Europe since 1750: evidence of increasing drought”. In: *International Journal of Climatology* 29.13, pp. 1894–1905.
- Burrell, Sean and Geoffrey Gill (Oct. 2005). “The Liverpool Cholera Epidemic of 1832 and Anatomical Dissection—Medical Mistrust and Civil Unrest”. In: *Journal of the History of Medicine and Allied Sciences* 60.4, pp. 478–498. ISSN: 0022-5045.
- Burton, N., J. Westwood, and P. Carter (2004). “GIS of the Ancient Parishes of England and Wales, 1500–1850 [computer Öle]”. In: *UK Data Archive [distributor]*.
- Callaway, Brantly and Pedro H.C. Sant’Anna (2021). “Difference-in-Differences with multiple time periods”. In: *Journal of Econometrics* 225.2. Themed Issue: Treatment Effect 1, pp. 200–230. ISSN: 0304-4076.
- Casillas, Shannon M., Carolyne Bennett, and Anne Straily (2018). “Notes from the field: Multiple cyclosporiasis outbreaks — United States, 2018”. In: *American Journal of Transplantation* 18.12, pp. 3072–3074.
- Chan, Christina H., Ashleigh R. Tuite, and David N. Fisman (Aug. 2013). “Historical Epidemiology of the Second Cholera Pandemic: Relevance to Present Day Disease Dynamics”. In: *PLOS ONE* 8.8, pp. 1–8.
- Chen, Chian-Ching, Chuan-Yao Lin, and Kow-Tong Chen (2019). “Epidemiologic features of shigellosis and associated climatic factors in Taiwan”. In: *Medicine* 98.
- Clark, Christine (1998). *The British Malting Industry Since 1830*. London: The Hambledon Press.
- Clark, Gregory (2001). “Farm Wages and Living Standards in the Industrial Revolution: England, 1670–1869”. In: *The Economic History Review* 54.3, pp. 477–505. ISSN: 00130117, 14680289.
- Cobbett, William (1833). *Cottage Economy*. John Doyle.
- Cornell, Martyin (2003). *Beer: The Story of the Pint*. Headline Book Publishing.
- Cutler, David and Grant Miller (Feb. 2005). “The role of public health improvements in health advances: The twentieth-century United States”. In: *Demography* 42.1, pp. 1–22. ISSN: 0070-3370.
- Desenclos, Jean-Claude A. et al. (1992). “The Protective Effect of Alcohol on the Occurrence of Epidemic Oyster-Borne Hepatitis A”. In: *Epidemiology* 3.4, pp. 371–374. ISSN: 10443983.
- Devoto, Florencia et al. (May 2012). “Happiness on Tap: Piped Water Adoption in Urban Morocco”. In: *American Economic Journal: Economic Policy* 4.4, pp. 68–99.

- Eber, MR et al. (2011). "Seasonal and Temperature-Associated Increases in Gram-Negative Bacterial Bloodstream Infections among Hospitalized Patients." In: *PLoS ONE* 6.9.
- Ferrie, Joseph P. and Werner Troesken (2008). "Water and Chicago's mortality transition, 1850–1925". In: *Explorations in Economic History* 45.1, pp. 1–16. ISSN: 0014-4983.
- Freeman, J.T., D.J. Anderson, and D.J. Sexton (2009). "Seasonal peaks in Escherichia coli infections: possible explanations and implications". In: *Clinical Microbiology and Infection* 15.10, pp. 951–953. ISSN: 1198-743X.
- Galiani, Sebastian, Paul Gertler, and Ernesto Schargrotsky (2005). "Water for Life: The Impact of the Privatization of Water Services on Child Mortality". In: *Journal of Political Economy* 113.1, pp. 83–120. ISSN: 00223808, 1537534X.
- Glaeser, Edward L. (2012). *Triumph of the city: How our greatest invention makes us richer, smarter, Greener, healthier, and happier*. Penguin Books.
- Goodman-Bacon, Andrew (2021). "Difference-in-differences with variation in treatment timing". In: *Journal of Econometrics* 225.2. Themed Issue: Treatment Effect 1, pp. 254–277. ISSN: 0304-4076.
- Al-Hasan, M.N. et al. (2009). "Seasonal variation in Escherichia coli bloodstream infection: a population-based study". In: *Clinical Microbiology and Infection* 15.10, pp. 947–950. ISSN: 1198-743X.
- Homan, Michael M. (2004). "Beer and Its Drinkers: An Ancient Near Eastern Love Story". In: *Near Eastern Archaeology* 67.2, pp. 84–95.
- Ingram, Lonnie O'Neal and Thomas M. Buttke (1985). "Effects of Alcohols on Micro-Organisms". In: *Advances in Microbial Physiology* 25. Ed. by A.H. Rose and D.W. Tempest, pp. 253–300. ISSN: 0065-2911.
- Jarvis, A. et al. (2008). "Hole-filled seamless SRTM data V4". In: *International Centre for Tropical Agriculture (CIAT)*.
- Johnson, Steven (2006). *The ghost map: The story of London's most terrifying epidemic*. Riverhead.
- Kaminsky, RG et al. (2016). "Marked seasonality of Cyclospora cayetanensis infections: ten-year observation of hospital cases, Honduras." In: *BMC Infect Dis*. 16.66.
- Kremer, Michael et al. (Feb. 2011). "Spring Cleaning: Rural Water Impacts, Valuation, and Property Rights Institutions". In: *The Quarterly Journal of Economics* 126.1, pp. 145–205. ISSN: 0033-5533.
- Lee, H.S., T.T. Ha Hoang, and P. et al. Pham-Duc (2017). "Seasonal and geographical distribution of bacillary dysentery (shigellosis) and associated climate risk factors in Kon Tum Province in Vietnam from 1999 to 2013." In: *Infect Dis Poverty* 113.
- Mahmud, Zahid Hayat et al. (May 2008). "Occurrence, seasonality and genetic diversity of Vibrio vulnificus in coastal seaweeds and water along the Kii Channel, Japan". In: *FEMS Microbiology Ecology* 64.2, pp. 209–218. ISSN: 0168-6496.
- Mathias, Peter (1959). *The Brewing Industry in England 1700-1830*. London: Cambridge University Press.
- McNicol, Geoffrey (2018). "Guido Alfani and Cormac Ó Gráda (eds.) Famine in European History Cambridge: Cambridge University Press, 2017. xi + 325 p. \$89.99; \$29.99 (pbk.)." In: *Population and Development Review* 44.1, pp. 182–183.
- Naous, Amal. et al. (2013). "Intestinal amebiasis: A concerning cause of acute gastroenteritis among hospitalized Lebanese children". In: *North American Journal of Medical Sciences* 5.12, pp. 689–698.
- Nye, John VC (2007). *War, Wine, and Taxes*. Princeton University Press.
- Richet, H. (2012). "Seasonality in Gram-negative and healthcare-associated infections." In: *Clin Microbiol Infect*. 934.
- Saad, N.J. et al. (2018). "Seasonal dynamics of typhoid and paratyphoid fever." In: *Scientific Reports* 8.6870.
- Schwab, F, P Gastmeier, and E Meyer (2014). "The Warmer the Weather, the More Gram-Negative Bacteria - Impact of Temperature on Clinical Isolates in Intensive Care Units." In: *PLoS ONE* 9.3.
- Sheth, Neela K., T R Wisniewski, and Timothy R. Franson (1988). "Survival of enteric pathogens in common beverages: an in vitro study." In: *The American journal of gastroenterology* 83 6, pp. 658–60.
- Snow, John (1855). "On the Mode and Communication of Cholera". In: *John Churchill*.
- Southall, H.R. and N. Burton (2004). "GIS of the Ancient Parishes of England and Wales, 1500-1850." In: *UKDA study number: 4828*.
- Standage, Tom (2006). *History of the world in six glasses*. Anchor Canada.

- Stopes, Henry (1885). *Malt and malting, an historical, scientific, and practical treatise*. Oxford University Press.
- Strachan, N. J. C. et al. (2013). "Identifying the seasonal origins of human campylobacteriosis". In: *Epidemiology and Infection* 141.6, pp. 1267–1275.
- Sun, Liyang and Sarah Abraham (2021). "Estimating dynamic treatment effects in event studies with heterogeneous treatment effects". In: *Journal of Econometrics* 225.2. Themed Issue: Treatment Effect 1, pp. 175–199. ISSN: 0304-4076.
- Tangtrongsup, Sahatchai et al. (2020). "Seasonal distributions and other risk factors for *Giardia duodenalis* and *Cryptosporidium* spp. infections in dogs and cats in Chiang Mai, Thailand". In: *Preventive Veterinary Medicine* 174, p. 104820. ISSN: 0167-5877.
- Troesken, Werner (2004). *Water, race, and disease*. MIT Press.
- Wachter, Kenneth (1998). "Levels of Demographic Randomness: Evidence from the Wrigley and Schofield Parish Series". In:
- Ward, Michael P (2002). "Seasonality of canine leptospirosis in the United States and Canada and its association with rainfall". In: *Preventive Veterinary Medicine* 56.3, pp. 203–213. ISSN: 0167-5877.
- Wrigley, E.A and R.S Schofield (2003). *Parish Register Aggregate Analyses, 1662-1811; 404 Data*. Colchester, Essex: UK Data Archive.
- Yun, J., M. Greiner, and C. et al. Höller (2016). "Association between the ambient temperature and the occurrence of human *Salmonella* and *Campylobacter* infections." In: *Sci Rep* 6.
- Zinn, Caleb et al. (2018). "How are water treatment technologies used in developing countries and which are the most effective? An implication to improve global health". In: *Journal of Public Health and Emergency* 2.0. ISSN: 2520-0054.

A. Online Appendix (Not for Publication)

Table 1 – The Effect of the 1780 Malt Tax Increase on Wintertime Mortality in Parishes with a Varying Numbers of Nearby Water Sources (Falsification Exercise).

	(1)	(2)	(3)
	Winter Deaths	Winter Deaths	Winter Deaths
Low Sources * Post	0.0217 (0.0559)		-0.0102 (0.0607)
High Sources * Post		-0.0787 (0.0536)	-0.0829 (0.0582)
Difference			.073
P-value			.27
Observations	7991	7991	7991

Note: This table compares winter mortality before and after the 1780 increase in the malt tax for parishes below the 75th percentile and below the 25th percentile in water quality. The first two columns estimate the coefficient on high and low water quality parishes separately, before including them in the same regression in column 3. In column 3, the difference between the high and low water quality coefficients is calculated and a p-value on the equality of the coefficients is estimated. In every specification, controls are included for parish population, regional wages, tea imports, parish and year fixed effects as well as a parish linear time trend. * $p < 0.10$, ** $p < 0.05$, *** $p < .01$.

Table 2 – The Effect of the 1780 Malt Tax Increase on Wintertime Mortality in Parishes with Varying Elevation (Falsification Exercise).

	(1)	(2)	(3)
	Winter Deaths	Winter Deaths	Winter Deaths
Low Elevation * Post	-0.0589 (0.0541)		-0.0757 (0.0582)
High Elevation * Post		-0.0291 (0.0568)	-0.0525 (0.0610)
Difference			.023
P-value			.73
Observations	7991	7991	7991

Note: This table compares winter mortality before and after the 1780 increase in the malt tax for parishes below the 75th percentile and below the 25th percentile in elevation. The first two columns estimate the coefficient on high and low water quality parishes separately, before including them in the same regression in column 3. In column 3, the difference between the high and low water quality coefficients is calculated and a p-value on the equality of the coefficients is estimated. In every specification, controls are included for parish population, regional wages, tea imports, parish and year fixed effects as well as a parish linear time trend. * $p < 0.10$, ** $p < 0.05$, *** $p < .01$

Table 3 – The Effect of the 1780 Malt Tax Increase on Wintertime Mortality in Parishes with Gley Soil (Falsification Exercise).

	(1)	(2)	(3)	(4)
	Winter Deaths	Winter Deaths	Winter Deaths	Winter Deaths
Post - Gley Soil	0.0560 (0.0572)	0.0518 (0.0572)	0.0533 (0.0574)	0.0549 (0.0597)
Log Population	-1.567*** (0.336)	-1.553*** (0.336)	-1.556*** (0.336)	-1.787*** (0.327)
Log Wage		0.324 (0.216)	0.320 (0.217)	0.369* (0.222)
Tea Imports x Gley Soil			-0.00885 (0.0224)	-0.0167 (0.0235)
Summer Deaths				0.0426*** (0.0134)
Observations	7991	7991	7991	7448

Note: This table compares winter mortality before and after the 1780 increase in the malt tax for parishes with gley soil, which is ideal for growing barley. In the first column population is controlled for, while the second column adds regional wages, the third column includes a control for tea imports and the fourth column adds a control for the summer death rate. In every specification, parish and year fixed effects as well as a parish linear time trend. * $p < 0.10$, ** $p < 0.05$, *** $p < .01$