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Research Paper

War, pandemics, and modern economic growth in Europe

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ABSTRACT

This paper contributes to the debate on Europe's modern economic growth using the statistical concept of long-range dependence. Different regimes, defined as periods between two successive endogenously estimated structural shocks, matched episodes of pandemics and war. The most persistent shocks occurred at the time of the Black Death and the twentieth century's world wars. Our findings confirm that the Black Death often resulted in higher income levels but reject the view of a uniform long-term response to the Plague. In fact, we find a negative impact on incomes in non-Malthusian economies. In the North Sea Area (Britain and the Netherlands), the Plague was followed by positive trend growth in output per capita and population, heralding the onset of modern economic growth and the Great Divergence in Eurasia.

1. Introduction

Economic historians still debate when modern economic growth, defined by a sustained increase in output per capita or per worked hour, accompanied by population expansion (Kuznets, 1966), first emerged. Some scholars (Clark, 2007) characterize the pre-Industrial Revolution era as a strictly Malthusian economy, with no long-term gains in living standards. By contrast, new quantitative research on pre-industrial European economies has found episodes of sustained growth that, although often reverted, led to higher levels of per capita income (van Zanden and van Leewen, 2012; Broadberry et al., 2015; Krantz, 2019; Prados de la Escosura et al., 2022). The literature has also emphasized the impact that health epidemics and wars have had on growth and divergence.

Yet the historical analysis of European long-run growth has been mainly impressionistic and there has been limited formal statistical testing of the break points in the time series and the factors that may have contributed to any sustained changes in growth, in no small part due to the lack of consistent long-run series. The recent availability of per capita GDP series for Western European countries since the late Middle Ages provides an opportunity to investigate economic growth in the very long run using modern time series analysis.

In this paper, we fill in this gap by investigating the role of historical events, such as wars and plagues, in structural breaks that conditioned trend growth on the basis of a sample study of six Western European economies: the United Kingdom, France, the Netherlands, Sweden, Italy and Spain, defined as per today borders during the last 700 years.

Our results define different structural breaks and reveal that the most persistent ones occurred at the time of the Black Death and the world wars of the twentieth century. Moreover, regimes, defined by endogenously estimated structural breaks at roughly similar dates for practically all countries, coincide with episodes of pandemics and war.

Our findings confirm that the Black Death often resulted in higher income levels but reject the notion of a uniform positive long-term response to the Plague. The higher income levels achieved were partly reverted in some regions, or became permanent in others. Thus, the Black Death emerges, together with the overseas expansion since 1500, and the Industrial Revolution, as a major event that

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contributed to growth and divergence across Europe (Pamuk, 2007; Broadberry, 2013; de Pleijt and van Zanden, 2016, A.M. de 2019; Jedwab et al., 2022). Frontier economies (namely, those with high land-labour ratios and abundant, unexploited resources) reacted negatively to the Black Death and average income levels experienced a long run decline (Álvarez-Nogal et al., 2020). Our results also confirm that wars appear to be associated with changes in growth and leadership within Europe (Voigtländer and Voth, 2013a; O'Brien, 2018).

These experiences suggest that, rather than strictly Malthusian, pre-industrial economic performance in some European regions would be better depicted as weakly Malthusian (and non-Malthusian in the case of frontier economies) with a series of growth reversal episodes in which increases in average incomes are largely cancelled out by subsequent episodes of decline (Broadberry and Wallis (2017).

Exceptionally, trend growth in per capita income occurred in Britain from the early 1600s onwards, and in the Netherlands in the wake of the Black Death, and neither of these countries suffered growth reversals (that is, phases of negative trend growth). In fact, if the North Sea Area as a whole is considered, per capita income gains and population expansion took place gradually after the Plague, a finding that dates the origins of modern economic growth further back in time.

2. Literature review

In the last two decades, quantitative research has produced estimates of per capita GDP for a growing number of countries in Europe and around the world. The new quantitative evidence improves on Maddison's conjectures on pre-industrial economies and provides grounds to argue that the roots of sustained economic growth in Western Europe since 1820 sinks its roots lie in the centuries between the Black Death and the Napoleonic Wars (Broadberry, 2013; de A.M. de Pleijt and van Zanden, 2019). This experience would have been restricted to some regions in north-western Europe, including Flanders, Holland, England and Wales, and Scotland, which became increasingly integrated into an economic unit, the *North Sea Area* (NSA), In the NSA, a distinctive reaction to the Black Death resulted in higher permanent income levels (Voigtländer and Voth, 2013a, 2013b; Jewab et al., 2022). Moreover, over time, the NSA exhibited differences in terms of demographic patterns (the European Marriage Pattern), human capital formation, institutions (commodity and factor markets, Parliaments), and international trade (Hajnal, 1965; Acemoglu et al., 2005; Broadberry, 2013; Carmichael et al., 2016; Dennison and Ogilvie 2014; de Moor and van Zanden, 2010; de Pleijt and van Zanden, 2016, A.M. de 2019; van Zanden et al., 2012; Henriques and Palma, 2019). Such a transformation eventually facilitated the onset of the Industrial Revolution. As a consequence of this successful growth process, widening gaps in terms of per capita income and structural change emerged between the NSA and most of continental Europe, and between Europe and Asia, which have been labelled the *Little* and the *Great Divergences*, respectively.

Fig. 1 presents the evolution of real per capita GDP in the six countries defined as per today borders considered over the first 600 years considered here. It can be observed that Britain (Britain and the U.K. are used indistinctively here) and the Netherlands, as representatives of the NSA, caught up with Italy and forged ahead of the remaining countries. In fact, outside the NSA, average income levels were not very different in the early nineteenth century from around the time of the Black Death. This also implied a reversal of fortunes, as Britain and the Netherlands exchanged positions with former leading economies, such as Italy and Spain (Fouquet and Broadberry, 2015; Prados de la Escosura et al., 2022).

However, no rigorous attempt has been made to put this narrative to the test using time series analysis, except for the case of Britain (Crafts and Mills, 2017). Their main finding is that zero trend growth prior to 1660 was followed by accelerations before and after the Industrial Revolution. This implies estimating the onset of modern economic growth nearly a century earlier than is often assumed (J.A. Goldstone, 2019). Moreover, their results lend support to Voigtländer and Voth's (2013b) depiction of the Black Death as an exogenous shock that allowed higher permanent income levels.

3. Econometric tools

The approach adopted by Crafts and Mills (2017) requires the historian exogenously to define regimes (called *segments* in their paper). In a second phase, they employ standard Dickey-Fuller unit-root tests to guarantee the usefulness of trend-stationary processes in such regimes. Thus, having defined regimes exogenously, the authors explore whether Britain's GDP per capita is driven by a trend-stationary (TS) or a difference-stationary (DS) process. As they point out, these processes consider only the two extreme scenarios of the effects generated by external shocks in the economy: transitory in the case of a TS process, and permanently in the case of a DS process.[1] The debate on whether economic time series are TS or DS processes remains inconclusive, partly because of the low statistical power of unit root tests.[2]

Our econometric strategy differs in two primordial aspects. First, break dates are considered to be unknown and, therefore, determined endogenously, which extends the treatment by Crafts and Mills (2017). Secondly, we follow a data-driven approach, popular in macroeconomics, which argues that external economic shocks are markedly more persistent than transitory ones and much less persistent than permanent ones.[3]

[1] Crafts and Mills (2017: 141, footnote 1). When a variable is stationary, the time series goes back to the original trend after a shock occurs. On the other, when the time series is non-stationary, particularly when the time series contain a unit root, its random behavior means the shock never dies out. These type of time series are also often called difference-stationary processes because a difference is necessary to convert the variable to stationary status, denoted as I(1) process.

[2] See Perron (2006) and Casini and Perron (2018) for comprehensive discussions. See also Mills (2016), who brings the debate to cliometrics.

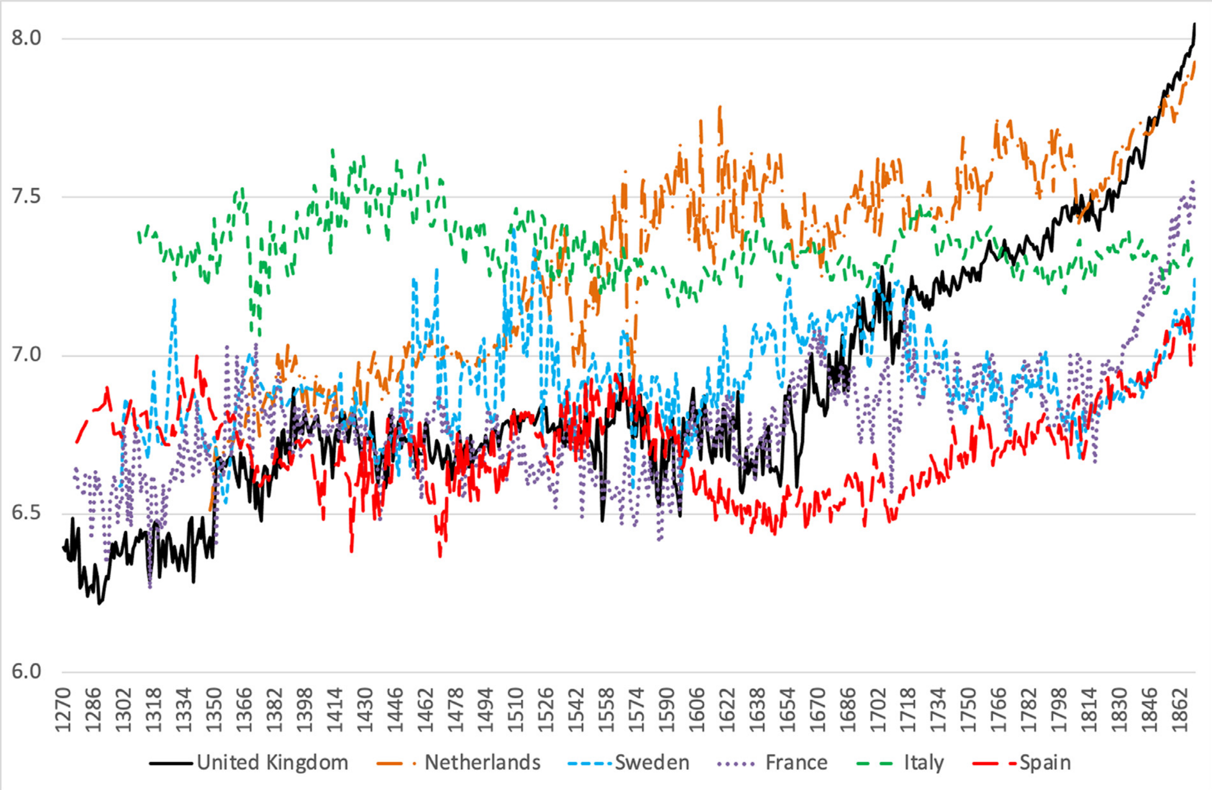

Fig. 1. Per Capita GDP in Six European Countries, 1270–1870 (Geary-Khamis $1990) (natural logs). Sources: Appendix.

3.1. Test for structural breaks

One of our goals in is this paper is to estimate when a particular event really exerted its effects, so we make no assumptions about the existence or location of breaks. We therefore relax Crafts and Mills's (2017) exogenous breaks approach and opt for a data-dependent algorithm to estimate the date of breaks.[4] Each pair of adjacent breaks defines a period known as 'regime', which may not necessarily coincide with those defined by the exogenous breaks sometimes used in historical analysis.

We use the Bai and Perron (1998, 2003a, 2003b) structural break method to estimate both the number and date of structural breaks in per capita GDP time series of the sample of European countries in a linear regression framework.

We are interested on testing and dating whether the linear trend of y_t changes over time. Then, we focus on the following simple specification,

$$y_t = \beta_{0,j} + \beta_{1,j}\ t + u_t,\ t = T_{j-1}, \dots, T_j. \tag{1}$$

for $j = 1, \dots, m+1$, where y_t is the per capita GDP series of the respective country analyzed, $\beta_{0,j}$ and $\beta_{1,j}$ $(j = 1, \dots, m+1)$ are the parameters to be estimated corresponding to the intercept and the slope of the linear trend fitted to the variable in the jth regime.

Following Bai-Perron methodology, we determine the number of breaks and their location using the SupF$(\ell + 1|\ell)$ test, which sequentially tests the null hypothesis of ℓ breaks against the alternative of $\ell + 1$ breaks.

The Bai-Perron testing procedure allows for up to nine breaks and up to ten regressors whose coefficients are the object of the test. The asymptotic critical values are computed via simulations (Bai and Perron, 1998). The methodology employs a sequential F test to infer how many shifts have the time series. The idea is that the full sample is divided into subsamples depending on a trimming parameter, denoted by h, which defines the minimal segment size that may be given as fraction relative to the sample size. The practitioner should choose and calibrate the trimming parameter h.

[3] Persistence measures the speed at which shocks to the particular economic variable die out. See the classic study by Diebold and Rudebusch (1989), or more recent works such as Caporale and Gil-Alana (2013), and Rodríguez-Caballero (2021).

[4] In our view, one never blindly selects a date to test for a break without prior information about the data. Then, even when a break time based on historical events is assumed exogenously, a (hidden) data analysis is previously performed. Moreover, there may be some periods when distinguishing breaks is highly cumbersome, for example, between the Great Depression and the start of World War II. In such cases, one certainly needs to make a prior data analysis to determine what event is the actual break according to the information provided by the time series.

The multiple structural changes are identified in the following manner: once the trimming parameter has been defined, for each m-subsample $(T_1, \ldots, T_m)$, denoted $\{T_j\}$, the least squares estimates of $\beta_{0,j}$, and $\beta_{1,j}$ are obtained by minimizing the sum of squared residuals

$$S_T(T_1, \ldots, T_m) = \sum_{j=1}^{m+1} \sum_{t=T_{i-1}+1}^{T_i} \left[y_t - \beta_{0,j} + \beta_{1,j}\, t\right]^2,$$

where S_T represents the sum of squared residuals in m-partition. Let $\hat{\beta}_0(\{T_j\})$ and $\hat{\beta}_1(\{T_j\})$ denote the resulting estimates. Next, substituting these into the sum of square residuals, gives the estimated break points $(\hat{T}_1, \ \ldots, \hat{T}_m) = \underset{T_1,\ldots,T_m}{\operatorname{argmin}} S_T(T_1, \ldots, T_m)$, where the minimization is taken over all partitions $(T_1, \ldots, T_m)$. This means that the break-points estimators are global minimizers of the objective function. The Bai-Perron method efficiently solves the minimization problem by dynamic programming. Zeileis et al. (2003) implement the algorithm using the R system for statistical computing. Our replication codes are available in Prados de la Escosura and Rodríguez-Caballero (2022).

3.2. The long memory approach

The main difference between TS and DS processes is in the impact of an external shock, both in its magnitude and its persistence; the latter is frequently referred to as the “memory” of the process. It is important correctly to quantify the persistence of a process in order to ascertain whether at least a part of the shock will return to its trend after a short period of time (immediately in the case of TS processes) or will be incorporated permanently into the level of the economic variable (in DS processes). However, a central property of macroeconomic time series is that the effect of a shock is long lasting and not limited to both extremes (Beran et al., 2016). When the shock of a time series is persistent enough but eventually forgotten at some point in time, it is said to have "long memory" or “long-range dependence”.

The long memory approach provides an alternative, more nuanced approach to the measurement of persistence. The paradigm of long-range dependence seems to be appropriate to describe the high degree of persistence that many economic time series exhibit in the form of long lasting effects of unanticipated shocks.[5]

Unlike Crafts and Mills (2017), we have opted here for a flexible approach to measure the persistence of the external shocks that have impacted GDP per capita. Thus, we go beyond the dichotomy between shocks that may vanish in the short term, and permanent shocks that never die out. We investigate whether some historical events provoke structural breaks in the trend of the series using the automatic Bai-Perron approach discussed above, and then define regimes with different levels of persistence. Our main goal is to establish whether some historical events that define regimes are short-memory, long lasting, or permanent because of their key role in determining how the GDP per capita responds to external shocks over time.

From a policy perspective, our work helps to understand whether the effects of transitory policies provoked in critical situations, such as in times of pandemics or wars, will be long lasting with different magnitudes depending on the source of the shock or, conversely, whether such policies will be either short-lived or permanent as the conventional stationary/non-stationary dichotomy suggests.

In long-memory models, the persistence is measured by a (fractional) parameter often denoted by d. Higher values of d represent longer lasting effects of shocks on the economic variable. In general, we can have different interpretations depending on the value of *d*.

a) A process with $d = 0$, referred to as I(0), such as in classical ARMA models, displays short memory, and implies that any shock that hits the series only has repercussions in the short-term because its impact will soon completely vanish.
b) A process will display long memory if $0 < d < 1$. In such cases, after an external shock hits the variable, the process will revert to its mean. This implies that any shock in the process has no permanent effect on the series, but will vanish at different speeds depending on the value of *d*.
c) A process will be stationary as long as $0 < d < 0.5$, while it will be non-stationary for $d \geq 0.5$.[6]
d) Processes with $d \geq 1$ are non-stationary and non-mean-reverting. Consequently, these type of processes imply that external shocks have permanent effects on the series.

There are different methods to estimate the long-memory parameter *d*. In this paper, we use a semiparametric method that does not require assumption of a parametric long-memory model: the Two-Step Exact Local Whittle (2ELW) estimator, proposed by Shimotsu (2010). This is a very useful estimator, particularly for economic data, because it accommodates unknown means and polynomial time trends. The estimator consistently covers both stationary and non-stationary regions. The reason why we opt for a semiparametric estimator is because it is agnostic vis-à-vis the short-run dynamics of the process and, therefore, robust to misspecifications.

In our analysis, we estimate the fractional memory d by 2ELW method for each one of the regimes previously estimated after implementing Bai-Perron methodology.

[5] See Beran et al. (2016) and Haldrup and Valdés (2017) for a review of long memory definitions.

[6] When the process is within the stationary region ($0 < d < 0.5$), the effect of shocks will last longer than in the purely stationary case ($d = 0$). When $0.5 \leq d < 1$, the process has time-dependent variance.

3.3. Data

We focus on a sample of six European countries (actually, European regions which correspond to the boundaries of modern countries) for which long series for real output and population are available for the last seven centuries. In order to make the series comparable in levels over space and time, we have expressed them in Geary-Khamis purchasing power parity 1990 dollars (that is, adjusted differences in the price level across countries). The construction of homogeneous series for each country that exposes the national coverage shortcomings of the GDP series is presented in the Appendix.

We are aware of the huge index number resulting from using such a remote fixed benchmark level, but since most of the debate has taken place in terms of G-K$1990 we have accepted it with all the necessary caveats (Prados de la Escosura, 2000).

4. Structural breaks and their persistence in Europe over the long run

4.1. Regime and persistence estimates

Major disruptions, such wars and pandemics, have been deemed the main drivers of income distribution in the very long run (Alfani, 2022; Milanovic, 2016; Scheidel, 2017). The enduring impact of wars provoked shifts in the relative position of countries in terms of per capita income. Moreover, historians have established connections between war, state building, and economic success under Mercantilism (Findlay and O'Rourke, 2007; O'Brien, 2018). Were wars and pandemics also the driving forces behind structural breaks?

Table 1 provides information about the different regimes defined by structural breaks for each country in the sample, with confidence intervals (CI), and the trend growth rates for per capita output in each regime.[7] In addition, it provides the fractional memory parameter d of each regime estimated by the 2ELW method. The estimation of breaks depends on the trimming parameter h, which has been calibrated for each individual case. The long memory parameter is estimated with bandwidths $m = T^{0.70}$, where T is the duration of each regime (also displayed in the same table). This bandwidth is often chosen in econometric literature to prevent others components of the time series (level or seasonal components, for instance) from interfering with a correct estimation of persistence.

An initial result from Table 1 appears to be that the timing of structural breaks largely coincides across the board. Thus, these breaks define regimes starting around 1340–1360, 1430–1460, 1520–1570, 1620–1650, 1800–1830, 1920, and 1940–1960. Why? Are there common causes of the structural breaks?[8]

The Black Death (1346–1353) and its aftermath marked a structural break across the board, ending a phase of rising output per capita, except for Italy and Sweden. A long post-Plague regime, which largely overlapped with the Hundred Years' War (1337–1453), was of recovery in some cases (Italy, the Netherlands, and Britain), but also of decline (France, Sweden and Spain). A new regime opened in the mid-fifteenth century with per capita income growth across most countries with the exception of France and Italy.

The next structural break initiated a phase that largely coincided with the emergence and expansion of the transatlantic trade with the Americas and Hapsburg Spain's European wars, including the Dutch Eighty Years' War (1568–1648) and Spain's annexation of Portugal (1580–1640). It turns out that while Spain experienced the highest negative trend growth rate (−0.58 per cent over 1573–1635) in any country of the sample during the seven century span considered, the Netherlands exhibited positive trend growth, as did France, while Britain stagnated. Sweden shared Spain's fate, with negative trend growth.

The strong contraction in Spain's real output per capita at the time of its overseas expansion calls for an explanation. It can be associated with the efforts to preserve its European Empire. Sustained increases in fiscal pressure on urban activities, the locus of the commercial and industrial expansion in the sixteenth century, in order to finance increasingly expensive imperial wars in Europe, placed an unbearable burden on the most dynamic sectors (Parker, 1975). This triggered de-urbanisation and led to a collapse of average real incomes from which early modern Spain never fully recovered (Prados de la Escosura et al., 2022). This is, of course, not an exclusive interpretation, and is compatible with other views that stress, for example, the impact of the massive arrival of silver in Spain (Drelichman, 2005; Charotti et al., 2022).

Another structural break corresponded to the Thirty Years' War (1618–1648) and a major episode of plague. Positive linear trend growth prevailed in this new regime, in which Britain excelled (0.77 per cent over 1629–1708), except in France, in which long stagnation took place until Waterloo, and Italy, where the plague was its main determinant (Alfani, 2013; Alfani and Percoco, 2019).

In this regime, Britain's trend growth rate more than doubled any previous growth during an expansionary phase in Western Europe. This represents an early success, at odds with the narrative that associates modern economic growth with the impact of the institutional changes brought about by the Glorious Revolution (North and Weingast, 1989) suggesting, instead, the effects of the institutional reforms in the aftermath of the civil war and republican rule (1640–83) (O'Brien, 2018).

A less widespread structural break, involving only Italy, Sweden, and Britain, happened at the time of the Spanish War of Succession (1701–14), and while British growth decelerated, Italy and Sweden experienced negative growth.

The Napoleonic Wars (1793–1815) witnessed a structural break in continental Europe, which was deferred to the first third of the nineteenth century in the British and Swedish cases. The new regime brought accelerated trend growth across the board, with

[7] To compute the Bai-Perron algorithm discussed in Section 3.1, we choose trimming parameters $h \in [0.08\ ,\ 0.12]$ to keep regimes large enough to focus on the most important historical events and avoid unnecessarily partitioning the time series.

[8] A caveat is required here: we cannot prove that the structural breaks result from wars or pandemics, but simply state their coincidence in time.

Table 1
Structural Breaks, Regimes, Persistence, and Per Capita GDP and Population Trend Growth in Europe.

	Regime	Period	Duration	CI 95%	2ELW	Trend Growth (%)	Population Growth (%)
SPAIN	1	1277–1341	65	(1339,1343)	1.07	0.06	0.23
	2	1342–1403	62	(1399,1404)	0.96	−0.33	−0.19
	3	1404–1462	59	(1459,1464)	0.57	0.26	0.27
	4	1463–1572	110	(1571,1573)	0.48	0.32	0.22
	5	1573–1635	63	(1634,1636)	0.26	−0.58	0.11
	6	1636–1814	179	(1812,1815)	0.46	0.18	0.38
	7	1815–1871	57	(1869,1873)	0.54	0.43	0.75
	8	1872–1961	90	(1960,1962)	0.91	0.74	0.73
	9	1962–2019	58	–	1.15	2.59	0.71
ITALY	1	1310–1340	31	(1339,1343)	0.57	−0.34	−0.07
	2	1341–1412	72	(1408,1413)	0.56	0.12	−0.42
	3	1413–1630	219	(1629,1631)	0.32	−0.16	0.34
	4	1631–1710	81	(1709,1711)	0.68	−0.13	0.38
	5	1711–1803	94	(1801,1807)	0.64	−0.45	0.20
	6	1804–1873	71	(1871,1873)	0.50	−0.01	0.82
	7	1874–1952	80	(1951,1953)	1.07	0.83	0.66
	8	1953–2019	68	–	1.41	2.33	0.30
FRANCE	1	1276–1356	81	(1354,1358)	0.25	0.17	0.31
	2	1357–1555	199	(1550,1556)	0.20	−0.09	0.21
	3	1556–1655	100	(1652,1656)	0.33	0.25	0.13
	4	1656–1815	160	(1814,1816)	0.31	−0.03	0.23
	5	1816–1938	123	(1936,1939)	0.61	1.28	0.22
	6	1939–2019	81	–	1.32	2.57	0.70
SWEDEN	1	1300–1362	63	(1361,1365)	1.24	−0.15	0.19
	2	1363–1455	93	(1452,1456)	0.54	−0.23	−0.02
	3	1456–1523	68	(1522,1558)	0.68	0.28	0.40
	4	1524–1608	85	(1607,1614)	0.40	−0.19	0.47
	5	1609–1716	108	(1715,1719)	0.30	0.28	0.57
	6	1717–1829	113	(1828,1830)	0.48	−0.16	0.54
	7	1830–1892	63	(1891,1893)	0.69	1.06	0.89
	8	1893–1956	64	(1952,1957)	0.87	2.24	0.60
	9	1957–2019	63	–	1.04	1.81	0.45
NETHERLANDS	1	1348–1576	229	(1570,1577)	0.60	0.24	0.32
	2	1577–1651	75	(1647,1654)	0.23	0.10	1.04
	3	1652–1806	155	(1804,1807)	0.50	0.19	−0.08
	4	1807–1949	143	(1948,1950)	0.6	0.80	1.08
	5	1950–2019	70	–	1.28	2.16	0.77
UNITED KINGDOM	1	1270–1350	81	(1349,1352)	0.42	0.11	−0.06
	2	1351–1434	84	(1433,1440)	0.61	0.21	−0.39
	3	1435–1526	92	(1520,1534)	0.31	0.14	0.25
	4	1527–1628	102	(1626,1629)	0.42	−0.02	0.66
	5	1629–1708	80	(1707,1712)	0.47	0.77	0.00
	6	1709–1834	126	(1833,1835)	0.68	0.33	0.79
	7	1835–1919	85	(1918,1920)	0.72	0.99	1.05
	8	1920–2019	100	–	1.01	2.07	0.38
NORTH SEA AREA	1	1348–1427	80	(1426,1451)	0.73	0.29	−0.40
	2	1428–1679	252	(1678,1683)	0.40	0.11	0.52
	3	1680–1808	129	(1807,1809)	0.57	0.25	0.37
	4	1809–1920	112	(1919,1921)	0.60	1.00	1.09
	5	1921–2019	99	–	1.07	2.10	0.48

Sources: Eq. (1) and GDP per head for the sample of countries from the Appendix. Replication codes to estimate regimes (columns 1–4), persistence estimates (column 5) and trend growths (columns 6 and 7) are available in Prados de la Escosura and Rodríguez-Caballero (2022).

the exception of Italy's stagnation, in which the French and British economies stood out. The institutional reforms triggered across Western Europe by the Napoleonic invasion and the collapse of Absolutism may have facilitated the onset of modern economic growth (Dincecco and Federico, 2021; Pfister, 2021; Prados de la Escosura and Santiago-Caballero, 2021).

The last structural breaks appeared in the aftermath of the two world wars: in the case of the UK, after World War I and the Spanish Flu pandemics; and in all other countries, after World War II, with positive and strong trend growth during the subsequent regimes.

A second aspect to be considered in Table 1 is the persistence of the shocks' impact as captured by the memory parameter d. Pandemic disease has recently been regarded as more persistent over time than any other event, war included (Jordá et al., 2022; Alfani, 2013). In the pre-industrial world, however, the difference between the effects of pandemics and war was blurred, as pandemics were often diffused across national boundaries by long-lasting wars (Voigtländer and Voth, 2013a).

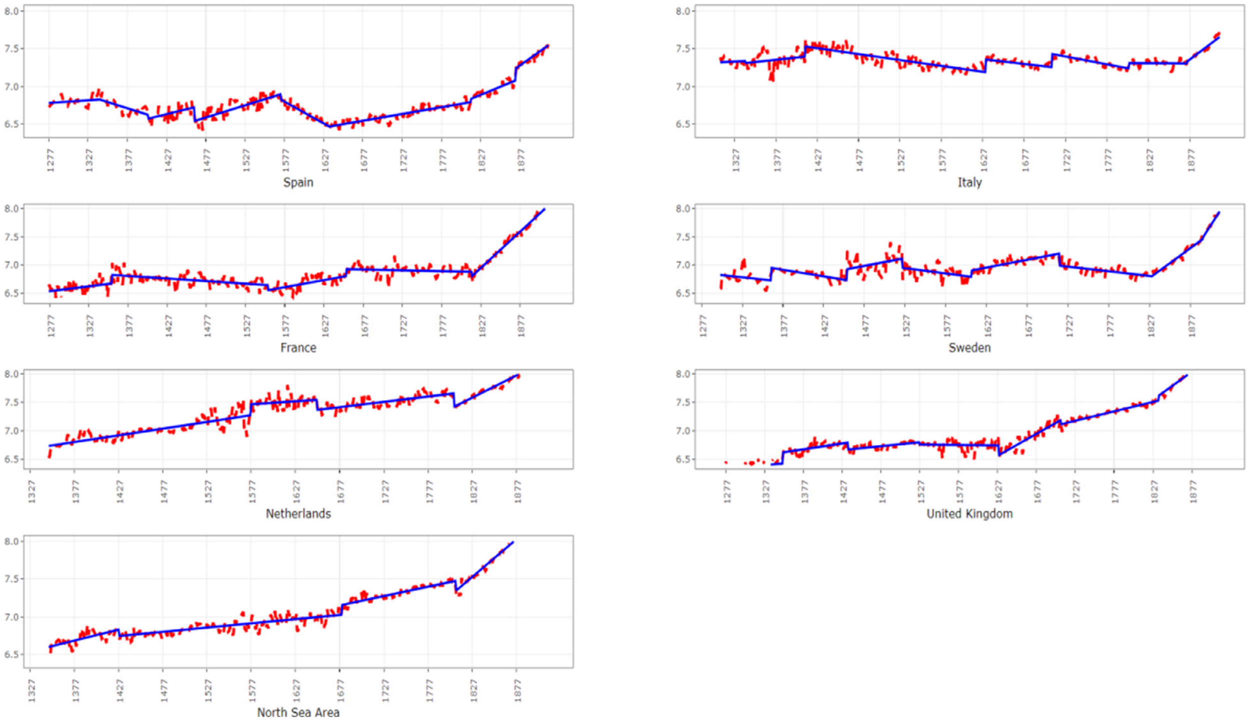

Fig. 2. Per Capita GDP in 6 European Countries and the North Sea Area, 1270–1913: Trend and Original Values (G-K $1990) (natural logs). Sources: Trend values derived with estimates trend growth rates from Table 1, column 7, and original values from the Appendix. See Prados de la Escosura and Rodríguez-Caballero (2022).

A glance at Table 1 suggests that the structural break originated by the Black Death represented a very persistent regime in Spain and Sweden with values of $d_{2ELW} = 1.07$ and 1.24, respectively. This implies that the Black Death constituted a permanent shock in these countries until the regime transitioned to the next one. In the cases of Britain and France, the impact of Black Death originated a regime with a relatively low persistence ($d_{2ELW} = 0.42$ and 0.25, $r$espectively) indicating that this shock was not permanent, but had transitory effects in both countries before eventually vanishing, but at a much slower pace than in Crafts and Mills's (2017:142) trend stationary scenario for Britain. In Italy and the Netherlands, structural breaks present a moderate persistence but not permanent effects ($d_{2ELW} = 0.57$ and 0.60, respectively).[9] It is worth stressing that in the case of Britain, a long memory process evolves towards higher persistence since the eighteenth century. The subsequent structural breaks, often concomitant with wars, had a lower degree of persistence. Only in the twentieth century did structural breaks around world wars exhibit strong persistence across the board.

4.2. *Malthusian Europe?*

Economists have tried to explain the transition from a society in which average income is stagnant to another in which its levels increase irreversibly over time (Hansen and Prescott, 2002). This approach assumes no sustained improvement in material living standards before 1820, when the First Industrial Revolution spread across Western Europe. The Unified Growth Theory, which models the transition from a Malthusian economy -in which land is in fixed supply, capital accumulation and technological change proceeds very slowly, and any increase in output per capita triggers a direct response on the part of the population- to a modern economy, provides a more nuanced approach that allows for mild per capita income growth in a late stage (Galor and Weil, 2000; Galor, 2011). What does historical evidence tell us? Does it support a dichotomy of stagnation or growth?

The joint outcome of wars and pandemics prior to the Napoleonic Wars was, according to Voigtländer and Voth (2013a), an increase in the endowment of land and capital per survivor that resulted in higher output per capita. Urbanization and military expenditure stimulated by higher average incomes would have led to new wars, the spread of disease, and, thus, to another increase in land and capital per worker, resulting in higher output per capita. This way, achieving higher income levels would have been compatible with a Malthusian context.

Does the evidence presented here fit in this interpretative framework? In the North Sea Area, a permanent higher income level followed the Plague, suggesting a positive answer (Fig. 2). The war, nonetheless, affected Britain much less than continental Europe.

[9] The fact that Italy is represented by north-central Italy might condition these results, as historical literature suggests a persistent impact on other Italian regions.

The case of Italy, with a trend growth rate of 0.12 per cent over 1341–1412, appears to confirm Voigtländer and Voth's (2013b) argument that the Black Death would have pushed average income to high levels that would not be reached again until centuries later, as post-Plague income levels were not recovered there until the late 19th century (Fig. 2). However, a similar thrust effect of pandemics and/or war does not seem to have taken place in Italy again. In fact, Italian economic decline in the seventeenth century has been associated with severe pandemic (Alfani, 2013).

The case of Spain appears to contradict Voigtländer and Voth's view because it was the pre-Plague level that was not reached again until the late 16th century (Fig. 2).

In the previous section, we defined different regimes by pairs of structural breaks associated with wars and pandemics. Do trend growth in population and per capita income in each regime evolve simultaneously in opposite directions as expected in the popular Malthusian version or, conversely, in the same direction? In the latter case, when sustained increases in population are accompanied by a long-term rise in per capita GDP, we are in the presence of what Simon Kuznets (1966: 20) labelled *modern economic growth*.

Table 1, cols. 6–7, offers trend growth rates for per capita GDP and population for each of the European regions that today conform the six countries considered (plus the North Sea Area, i.e. the population weighted average of Britain and the Netherlands). The evidence appears to fit the Malthusian pattern for some countries in different periods: Britain until the seventeenth century, France from the Black Death up to the Napoleonic Wars, Italy until its Unification (1861), the Netherlands during the late seventeenth and eighteenth centuries, and Sweden during the sixteenth and eighteenth centuries, confirming Alfani and Ó Gráda (2018) intuition. However, this does not seem to fit the cases of Sweden between the Plague and the early 1500s, or Spain, in which per capita GDP and population evolved together over the whole considered period and, even when they show opposite signs, as in 1573–1635, the negative output per capita growth coincides with a sharp deceleration in population growth.

It is worth stressing that the post-Black Death trend growth acceleration appears to be consistent with the Malthusian narrative for most countries, but how can the negative trend growth in Spain and Sweden be explained? The existence of a frontier economy with abundant natural resources and scarce population provides an explanatory hypothesis. The fact that factor proportions - high land-labour ratios in pre-Plague Spain and Sweden - were similar to those in post-Plague Western Europe (Pamuk, 2007) helps explain why the Black Death had only negative consequences for their economies. In Spain, the pre-existing fragile equilibrium between resources and labour was broken by the Black Death, with devastating economic consequences, despite its comparatively milder demographic impact (Álvarez-Nogal and Prados de la Escosura 2013; Álvarez-Nogal et al., 2020). Furthermore, the frontier economy may also help to explain the inverse behavior of Sweden and Spain compared with the rest of the countries in the sample a long time after the Black Death.What does all this evidence tells us about the origins of modern economic growth? All countries except the Netherlands and Britain present trend growth reversals; in most of continental Europe, irreversible growth only took place from the Napoleonic Wars (1793–1815) onwards, and peak levels achieved in earlier periods were not overcome until the early nineteenth century or later.

In Britain, no growth reversals exist, even though zero trend growth is found between 1527 and 1628, so a positive trend growth emerges since 1270.[10] Nonetheless, trend growth accelerated from the first third of the 17th century onwards, making Britain a precocious case in Europe. In the Netherlands, the absence of growth reversals implies a positive trend growth since 1348, although an acceleration took place after 1807.

Thus, if we approach the question at individual country level, it is possible to affirm that while the Netherlands experienced mild growth trend in real output per capita after the Plague, in the case of Britain, trend growth can be dated from the early 1600s, confirming previous findings by Crafts and Mills (2017). Yet, if we look at regions, rather than countries, it emerges that positive trend growth in per capita income and a sustained increase in population took place in the North Sea Area from the Black Death onwards (Table 1, cols. 6–7).

5. Final remarks

In this paper, we have investigated the origins of modern economic growth and the *Little Divergence* in Europe with the help of a 'long memory' approach. Structural breaks in per capita GDP defining different phases or regimes are located for a sample of European countries over seven centuries. It is worth noting that structural breaks frequently coincided with wars and pandemics, and those that occurred around the Black Death and World Wars I and II were the most persistent.

We find that the Black Death often resulted in higher income levels, as posited by Voigtländer and Voth, but the response to the Plague was far from uniform and its effect was not permanent in every country. Furthermore, in frontier economies, the Black Death had a negative effect upon average income levels. This calls for analysis of the endogenous response to the Plague across countries.

Our results contradict the binary, stagnation-growth, description of pre- and post-Industrial Revolution economic behavior. Historical evidence suggests a more nuanced view. Even if an inverse relationship between output per capita and population tendencies is often found, the timing differs across countries and a weak, rather than a strict Malthusian pattern better reflects the European experience, since average incomes gradually rose between the Black Death and the Napoleonic Wars. Moreover, exceptions to the Malthusian regime are not negligible, as in frontier economies capita income and population moved together.

A key question in the historical debate is whether the onset of modern economic growth took place in Europe before the mid-eighteenth century. We provide an affirmative answer here. When countries are considered individually, we find that, in Britain, trend growth in per capita income occurred from the early 1600s onwards, while in the Netherlands it dates back to post-Black Death

[10] However, one may ponder what would have been the outcome in Britain had demographic shocks such as those of the late 18th century taken place a century earlier: The possibility of a growth reversal in such a scenario does not seem far-fetched (see Crafts and Mills, 2021).

era, and neither suffered growth reversals after the Plague. If, alternatively, we focus on distinctive regions, we find that in the North Sea Area, sustained per capita income gains together with population growth took place gradually after the Plague.

Dating the origins of MEG back to the post-Black Death era has implications for the global debate on the origins of the Eurasian *Great Divergence*, namely, the increasing gap in average incomes between Europe and Asia. While in Broadberry-van Zanden's narrative, slow but sustained per capita income growth since 1348, accompanied by structural transformation, saw the North Sea Area to forge ahead of the rest of Europe and Asia, according to the California School, continuous gains in average incomes simultaneous to population expansion were absent in Europe until as late as 1750. The episodes of growth observed in north-western Europe would have not been significantly different from previous 'efflorescence' experiences, simply isolated and short phenomena that, when exhausted, led to another Malthusian equilibrium (Goldstone, 2002).

Thus, our finding of an early trend growth in per capita income in the North Sea Area implies that the roots of the *Great Divergence* date back to the aftermath of Black Death and European overseas expansion. Such an interpretation, in line with the view of an earlier European primacy (Braudel, 1973; Jones, 1981; Maddison, 2007), lends support to Broadberry-van Zanden's interpretation and rejects the interpretation by the California School (Frank, 1998; Pomeranz, 2000; Goldstone, 2002; J.A. 2019), which dates the beginnings of the *Great Divergence* at the onset of industrialization in north-western Europe.

Declaration of Competing Interest

None.

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Appendix. Per Capita GDP and Population Series

For the most recent period, per capita GDP and population series from Conference Board (2019) and the Maddison Project Database (2013) have been used for all countries except Spain, and spliced with data from historical national accounts. The construction of homogeneous series for each country has been as follows.

Italy. Conference Board (2019) series were spliced with Baffigi's (2012) estimates for 1861–2010, and then projected backwards with Malanima's (2011) estimates for North and Central Italy back to 1310, assuming the rest of the country evolved similarly. This astringent assumption introduces a bias of unknown impact, which it is the price paid for having continuous series over seven centuries.

Netherlands. We have used Conference Board (2019) and Maddison Project Database (2013) from 1870 onwards and projected them backwards with estimates by van Zanden and van Leewen's (2012) to 1807 and, then, again, to 1348, on the basis of series for the Holland province, under the assumption that the whole country evolved similarly.

United Kingdom. We have started from the present day definition - Great Britain (that is, England, Wales, and Scotland) and Northern Ireland - for which estimates exist dating back to 1870 (Bank of England, 2018), and projected them back to 1700 using Broadberry et al. (2015) estimates for Great Britain, and, then, for England, back to 1270. Again, we assumed that the regions not included evolved similarly. We will use the UK and Britain as synonymous terms in the rest of the paper.

Spain. Prados de la Escosura (2017, updated) series for 1850–2019 were projected backwards to 1277 with Prados de la Escosura et al. (2022) estimates.

Sweden. Conference Board (2019) series for 2010–2019 were projected backwards with Krantz and Schön's (2007) series for 1800–2010, then, with Schön and Krantz's (2012), for 1560–1800, and linked to Krantz's (2017) series for 1300–1560.

France. In order to derive yearly series for France over 1276–2019, Conference Board (2019) and Maddison Project (2013) estimates from 1950 onwards were projected back to 1789 with Toutain's (1997) estimates and, then, again with Ridolfi and Nuvolari's (2021) series to 1276.

North Sea Area. GDP per capita obtained as the population weighted average of Britain and the Netherlands.

Per capita GDP series are expressed in Geary-Khamis purchasing power parity 1990 dollars to facilitate their comparability. Thus, for each country we have projected back and forth the 1990 benchmark level derived by Maddison (1995) with the volume indices from historical national accounts described above.

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