Localized or generalized growth? Structural breaks and the two views of the industrial revolution

Pereira, Alvaro S.

Localized or Generalized Growth? Structural Breaks and the Two Views of the Industrial Revolution

Alvaro S. Pereira [*]

Abstract: *»Lokalisiertes oder generalisiertes Wachstum? Strukturelle Umbrüche und die zwei Sichtweisen der industriellen Revolution«*. This paper uses an endogenous structural breaks procedure that provides additional evidence on two alternative views of the British Industrial Revolution. The tests are carried out for two periods: 1750-1800 and 1800-1850. The empirical results show that structural breaks occurred in most British industries throughout the period, suggesting that growth was pervasive and not localized in the iron and cotton industries. Growth accelerated in most industries throughout the period, which indicates an increasing dynamism of the British economy.

Keywords: Industrial Revolution, structural breaks.

1. Introduction

Although its long-term consequences are indisputable, there is still widespread debate on whether or not the Industrial Revolution represented a major discontinuity in the process of British economic development. Deane and Cole (1969) suggest that the Industrial Revolution was a period in which there was a sharp acceleration in economic growth. In contrast, the pioneering studies of Crafts and Harley (Harley 1982, Crafts 1985, Crafts and Harley 1992) indicate that GDP growth was slow during the early Industrial Revolution and total factor productivity (TFP) grew very gradually[1]. The Crafts and Harley estimates also suggest that output and productivity growth accelerated only in a couple of "dynamic" industries (cotton and iron), implying that innovation and growth were localized in these industries. According to them, outside these sectors, the British economy was still dominated by small-scale industries that were characterized by low productivity and lack of innovation.

---

* Address all communications to: Alvaro S. Pereira, School for International Studies, Simon Fraser University Vancouver, 515 West Hastings Street, Vancouver, BC, V6B 5K3, Canada; e-mail: apereira@sfu.ca.

1 Deane and Cole (1969) estimate that output and industrial growth rates accelerated from less than 1 percent per year to a staggering 3.4 percent in the 1780s. Crafts and Harley (1992) estimate that GDP growth increased from 0.6 per cent per year before 1780 to 1.4 percent from 1780-1800 and to 1.9 percent between 1800 and 1830. According to them, TFP grew at an average of 0.1 percent per year before 1800 and around 0.3 percent from 1800 to 1830.

In contrast, opponents of the gradualist view, such as Berg (1994), Berg and Hudson (1992) and Esteban (1994), have claimed that the macro estimates suffer from a series of flaws[2], which imply that the Crafts-Harley estimates might underestimate output and productivity growth, but also might entail an unnecessary homogenization of a diverse and dynamic economy. In his classic work on technological change, Mokyr (1990) has also indicated that innovation seems to have been pervasive during the Industrial Revolution. In spite of these criticisms, during the last two decades the pendulum of research on the Industrial Revolution seems to have swung increasingly in the favor of the gradualists. The Industrial Revolution appears to be losing its revolutionary character, being now pictured as just a non-exceptional growth spurt caused by the "localized" growth of the textile and iron industries (Clark 2001, Goldstone 2002).

In the last few years, these two views of the Industrial Revolution have been assessed in a variety of ways. By analyzing trade flows between Britain and the rest of the world, Temin (1997, 2000) presents evidence in favour of generalized industrial growth, showing that British exports included products from both the dynamic and traditional sectors, such as paper, soap, and woollen goods. In contrast, Harley and Crafts (2000) use a CGE model in which the exports of the traditional industries increase even in the absence of TFP growth. According to them, the rise in the volume of exports of the most traditional sectors can be explained by the need to finance increasing food imports (fuelled by rapid population growth), the quality of the British goods and a poor substitutability of other countries' goods. In turn, Greasley and Oxley (2000) pursue an alternative approach by analysing the properties of time series of industrial output data in a sample of 26 industries obtained from Walther Hoffmann (1955) during the 1815-1860 period. They conclude that early industrialization was defined by a small number of stochastic common trends. Granger-type causality tests also suggest that cotton textiles and iron products (and possibly sugar) were the leading sectors in British industrial growth. Greasley and Oxley thus propose an intermediate position between the two views of the Industrial Revolution, in which several technological waves spread across the British economy with different impact on individual industries.

This paper also exploits the properties of disaggregated time series in order to compare the two views of the Industrial Revolution. In this context, this study uses an econometric technique recently developed by Vogelsang (1997) that endogenously searches for structural breaks of disaggregated time series. The results of the Vogelsang structural breaks tests provide additional evidence on the localized versus generalized growth controversy, allowing us to see

[2] Including data unreliability, the difficulty in assigning accurate weights to the several sectors of the economy, wide regional disparities, the reliance on adult male data, and the difficulty of estimating non-factory production.

whether or not structural breaks were restricted to the cotton and iron industries (and hence growth was localized). The results of the Vogelsang structural breaks tests provide additional evidence supporting the view that industrial growth was not localized the Industrial Revolution and that output growth accelerated across most industrial sectors throughout the period. The results from the Vogelsang tests also provide additional information about the statistical properties of the British historical industrial statistics. In this sense, this paper extends the pioneering work made by Crafts and Mills (1994, 2004) and by Greasley and Oxley (1994, 2000) on British historical time series during the Industrial Revolution. The results in this paper show that, similarly to the findings related to the aggregate industrial indexes, most individual industrial time series also exhibit structural breaks.

The paper proceeds as follows. Section 2 describes the Vogelsang structural breaks tests and presents results for two periods, 1700-1800 and 1800-1850. Section 3 reports the results from the estimation of the impulse response functions, and the last section concludes.

2. Structural Breaks and the Two Views of the Industrial Revolution

Testing for structural breaks in the context of the British Industrial Revolution is not a completely novel approach. Namely, Crafts and Mills (2000, 1994) found that an aggregate index of industrial output followed a segmented quadratic trend and had breaks occurring in 1776 and in 1831. However, similar tests have not been carried out in disaggregated data, especially at the sector level. This paper tries to remedy this lacuna by testing for structural breaks in a plethora of industrial time series as well as other variables such as trade and patent series.

The work by Crafts and Mills and the estimates of Crafts and Harley (1992) both suggest that the growth process of the British economy after the mid-eighteen century was not smooth: aggregate growth increased in the last decades of that century, and then it accelerated further in the early nineteenth century, decelerating afterwards. These estimates based on aggregated industrial data seem to indicate that there were (at least) two possible structural breaks during the Industrial Revolution. Based on these studies, and in order to simplify the analysis, the period of analysis was divided into two broad sub-periods: 1750-1800 and 1800-1850[3]. This subdivision of the time series is necessary because the Vogelsang tests described below are only able to detect a

[3] Tests were performed for other sub-periods but did not significantly change the results obtained.

single break. Hence, if there were multiple breaks, the Vogelsang test would pick up the most likely break, but not other less significant ones.

The hypothesis to be tested is the following: if the "localized" growth hypothesis is correct, then: 1) in the period before 1800, we should be able to detect structural breaks only in the most dynamic sectors (cotton and iron) of the British economy, and 2) most industrial series should exhibit a structural break after 1830 (i.e. the period when, according to some gradualists[4], modern growth emerges). On the other hand, if the "generalized growth" view is correct, then most series should exhibit breaks in their trends in *both* periods, which implies that most industries were subject to structural transformations *throughout* the Industrial Revolution.

Data were obtained from a variety of sources. Most industrial output data are from Hoffmann's (1995) work on British industrial growth. Many series in the Hoffmann data start in early eighteen century, and the Hoffmann indices contain not only disaggregated data for several industries, but also other important variables, such as the number of bankruptcies, an index of consumer goods, and an index of producer goods. Some other variables (e.g. beer, steel, shipbuilding, etc.) start only at the end of the eighteenth century or after 1800. The Hoffmann data were chosen because they still provide the best source of disaggregated data of the British Industrial Revolution (Greasley and Oxley 2000). In addition to the Hoffmann data, Feinstein's (1988) pig iron output data are also used, as well as the number of patents collected by Dutton (1984) and MacLeod (1988), total exports and imports as reported in Mitchell (1988), and the Crafts-Harley (1992) total industrial output indexes. All in all, for the period 1750-1800, we have 16 industrial series, 6 aggregate indexes and 5 other variables (including bankruptcies, exports, imports, and patents), whereas for the period 1800-1850 there are 30 individual industries as well as 11 other series.

The Vogelsang SupWald Tests

In order to test for structural changes in each individual series, the SupWald (or $SupF_t$) Vogelsang test was selected due to its advantages in comparison to other tests for structural breaks, and because it provides endogenous estimates of the structural break date without specifying *a priori* the break years[5]. In previous tests for structural breaks, some restrictions (e.g. non-trending regressors, stationarity, and no serial correlation) were relaxed, but not all simultaneously. In contrast, the Vogelsang SupWald procedure is a test for a structural break in

4 See, for instance, Clark (2001) and Goldstone (2002).

5 These tests were also carried out by Ben-David and Papell (1995, 1997) for GDP and export and import ratios.

the trend function of a univariate time series, which allows for serial correlation and is robust in the presence of a unit root. The features of this test are important for this paper, since most series analyzed have trends, exhibit serial correlation, and have unit roots. According to the methodology developed by Vogelsang (1997) and Perron (1989), the tests are divided into two stages. In the first stage, Phillips-Perron unit root tests are performed. These results are reported in table 1.

Table 1: Phillips-Perron unit roots tests, 1750-1850

	1750-1800		1800-1850	
	t-stat	**P-value**[6]	**t-stat**	**P-value**
Industries				
Beer			-3.259	0.085
Breads and cakes			-4.439*	0.005
Building			-0.155	0.992
Coal	-5.448*	0.000	-0.552	0.978
Copper	-3.425	0.068	-2.755	0.220
Copper Ore	-2.134	0.518	-2.223	0.467
Cotton goods	1.015	1.000	-2.535	0.311
Cotton yarn	0.180	0.998	-2.170	0.495
Flour			-3.985*	0.016
Hemp products			-5.474*	0.000
Iron (Feinstein)	2.501	1.000	0.270	0.998
Iron (Hoffmann)			-1.456	0.832
Iron and steel products			-1.665	0.752
Leather			-3.854*	0.022
Leather goods			-3.724*	0.030
Linen yarn	-3.309	0.079	-5.086*	0.001
Linens	-3.318	0.078	-5.730*	0.000
Malt	-7.325*	0.000	-5.791*	0.000
Ocean shipping	-1.181	0.904	0.601	0.999
Paper	-2.593	0.285	-0.047	0.995
Shipbuilding			-2.883	0.177
Silk goods			-5.624*	0.000
Silk thread			-5.099*	0.001
Spirits			-2.613	0.277
Steel			-1.370	0.858

[6] MacKinnon (1996) one-sided p-values. The Phillips-Perron test critical values are, –4.0524(1% level), - 3.455 (5% level), and –3.153 (10% level).

Table 1 continued…

Sugar	-5.984*	0.000	-3.448	0.056
Tin	-6.484*	0.000	-3.001	0.142
Tobacco			-2.520	0.318
Woollen cloth	-3.185	0.097	-5.418*	0.000
Woollen yarn	-2.885	0.187	-4.546*	0.003
Aggregate indexes				
Consumer goods	-0.325	0.989	-2.832	0.193
Producer goods	0.523	0.999	-0.117	0.993
Total Industry (Hoffmann)	4.717*	1.000	2.628	1.000
Total Industry (Hoffmann 2)	0.732	0.999	-1.387	0.853
Total Industry (Crafts and Harley 1)	-3.140	0.103	-1.643	0.762
Total Industry (Crafts and Harley 2)	-1.194	0.906	-1.566	0.792
Miscellaneous Variables				
Bankruptcies	-5.285*	0.000	-4.614*	0.003
Patents (Hoffmann)	-3.490*	0.046	-0.456	0.985
Patents (MacLeod)	-3.512*	0.044	-2.234	0.461
Exports	1.548	1.000	-3.787	0.025
Imports	5.644*	1.000	-3.812	0.022

* reject unit root at the 5% level of significance

This is an important stage of the Vogelsang tests, because the critical values depend on whether the series is stationary or contains a unit root. For the 1750-1800 period, we can reject the null of a unit root for 4 out of 16 industrial series, as well as 6 out of 11 of the remaining series. For 1800-1850, the null can be rejected for 12 out of 30 industries and 1 out of 11 of the other series. Although tests for unit roots in these series have a strong tendency to reject the unit root hypothesis, we erred on the side of caution and always used the unit root critical values due to the low power of these tests. The use of the unit root critical values changes little. All but 3 of the 68 series tested did not exhibit a structural change as a consequence of using the unit root critical values. In the second stage of the Vogelsang procedure, the following equations are estimated:

$$y_t = \mu + \beta t + \delta t^2 + \theta DU_t + \gamma_1 DT_t + \gamma_2 DT2_t + \sum_{j=1}^{k} c_j y_{t-j} + \varepsilon_t \quad (1)$$

$$y_t = \mu + \beta t + \theta DU_t + \gamma DT_t + \sum_{j=1}^{k} c_j y_{t-j} + \varepsilon_t \quad (2)$$

$$y_t = \mu + \theta DU_t + \sum_{j=1}^{k} c_j y_{t-j} + \varepsilon_t \quad (3)$$

where y_t represents the series to be tested, T_B denotes the time of the break or the period at which the change in the parameters of the trend function occurs, *t* represents a linear trend, and t^2 denotes the square of this linear trend. Following Ng and Perron (1995) and Perron (1989), the general-to-specific data dependent method for selecting the lag length *k* is used: start with k*=8 and if the t-statistic on γ_j was greater than 1.6 in absolute value k was set to 8, if not, the last lag was removed and the test repeated. In addition, the break dummy variables have the following values: $DU_t = 1$ if $t > T_B$, zero otherwise; $DT_t = t-T_B$ if $t > T_B$, zero otherwise; and $DT2_t = (t-T_B)^2$ if $t > T_B$, zero otherwise[7]. Each model is then estimated sequentially for *each* possible *break year* with 1 percent trimming, i.e., for $0.01T < T_B < 0.99T$, where T is the number of observations. In Model (1), *SupWald* is the maximum, over all possible trend breaks, of three times the standard F-statistic for testing $\theta = \gamma_1 = \gamma_2 = 0$. In Model (2), *SupWald* is the maximum, over all possible trend breaks, of two times the standard F-statistic for testing $\theta = \gamma = 0$. Finally, in Model (3), *SupWald* is the maximum, over all possible trend breaks, of the standard F-statistic for testing $\theta = 0$. In each model, the null hypothesis of no structural change is rejected if *SupWald* is greater than the critical value.

Intuitively, the existence of structural breaks in the time series *y* would indicate that the Industrial Revolution led to significant changes in *y*, originating a break in the trend of that series. For instance, if the Vogelsang tests are able to reject the null of no structural change for, say, industrial output, then we can be confident that, within the relevant significance interval, the trend of industrial output has undergone a structural transformation after the break occurred. Comparing the pre- and post-break trend growth rates allow us to measure the magnitude of the change in the trend.

Results

Table 2 summarizes the results of the Vogelsang tests for the 1750-1800 period. In terms of model selection, Model I is the preferred specification for 15 out of the 27 series. More significantly, if we use the unit root critical values, the hypothesis of no structural break can be rejected for all series but copper, coal, and both patent series. If we use the stationary critical values, both patent series also exhibit a structural break in 1792. All structural breaks but ocean shipping occur in the last quarter of the eighteenth century, suggesting that industrial growth was undergoing significant structural changes across most industrial sectors during the early stages of the Industrial Revolution.

[7] For the ADF tests, the asymptotic critical values for the 1%, 5% and 10% levels are, respectively -3.571, -2.922 and -2.599 For the KPSS tests, the asymptotic critical values for the 1%, 5% and 10% levels are, respectively, 0.216, 0.146 and 0.119.

Table 2: SupWald values and break years (1750-1800)[8]

	Break Year	Model	SupWald	Signif.	Pre-break trend growth	Post-break-trend growth
Industries						
Building	1792	I	42.28	1%	1.5	0.8
Coal	No break	-	-	-	-	-
Copper	No break	-	-	-	-	-
Copper Ore	1787	II	23.13	10%	3.3	4.5
Cotton goods	1792	I	64.5	1%	5.7	8.5
Cotton yarn	1781	I	63.97	1%	3.1	7.9
Iron (Feinstein)	1790	I	61.26	1%	1.7	8.1
Linens	1781	II	39.37	1%	1.2	2.4
Linen yarn	1781	II	39.18	1%	1.2	2.3
Malt	1798	II	23.11	10%	0.05	-3.7
Ocean shipping	1757	I	34.94	5%	-3.9	2.7
Paper	1777	I	61.11	1%	1.4	1.7
Sugar	1797	I	40.28	1%	1.4	8.4
Tin	1783	I	38.35	1%	0.1	0.3
Woollen cloth	1773	I	33.31	5%	0.6	1.6
Aggregate indexes						
Consumer goods	1788	II	65.56	1%	1.3	2.3
Producer goods	1772	I	84.89	1%	1.6	2
Total Industry (Hoffmann)	1780	I	406.38	1%	1	3.4
Total Industry (Hoffmann 2)	1788	II	89.52	1%	1.3	2.5
Total Industry (Crafts and Harley 1)	1773	II	53.48	1%	0.7	1.7
Total Industry (Crafts and Harley 2)	1773	I	33.99	5%	0.8	1.6
Miscellaneous Vari-ables						
Bankruptcies	1792	I	76.71	1%	2.2	-4.9
Patents (Hoffmann)	No break	-	-	-	-	-
Patents (MacLeod)	1792	II	17.46	-	-	-
Exports	1781	I	34.79	5%	-0.03	5.3
Imports	1784	I	131.84	1%	1.3	5.5

[8] For Model 1, the critical values or the 1, 5, and 10 percent significance are 38.35, 31.29, and 27.99 in the unit root case, respectively. For Model 2, the critical values for the 1, 5, and 10 percent significance are respectively, 30.36, 25.1, and 22.29.

In terms of the industrial data, the most significant result of the Vogelsang tests is that, for the majority of the series analysed, the post-break trend growth is higher than the pre-break trend growth. As expected, the highest rates of post-break trend growth in the sample occurred in the most dynamic sectors, cotton goods (8.5%), cotton yarn (7.9%) and iron (8.1%), but also in the sugar industry (8.4%)[9]. However, for most other series, there is also an acceleration in trend growth rates after the structural breaks occurred: from 3.3% to 4.5% in copper ore, from 1.2% to 2.4% in linens, from 1.2% to 2.3% in linen yarn, from 1.4% to 1.7% in the paper industry, from 0.1% to 0.3% in the tin industry, and from 0.6% to 1.6% in the woollen cloth industry. The exceptions to this general tendency of trend growth acceleration occurred in the building industry (from 1.5% to 0.8%), and the malt industry (from 0.05% to –3.7%). For the building industry, the decline in trend growth rates reflect the 1790s downturn that occurred in this sector, as reported by the classic work of Cairncross and Weber (1956).

All in all, the results of table 2 show that during the Industrial Revolution growth accelerated in most industries following the structural breaks, which suggests an increasing dynamism of the British economy during the early Industrial Revolution. More importantly, the structural breaks were not confined to iron and cotton, which seems to suggest that growth was generalized and accelerating across most British industrial sectors.

The aggregate indexes also show that trend acceleration occurred during the early Industrial Revolution. Trend growth rates of consumer goods increased from 1.3% to 2.3% after 1788, whereas trend growth of producer goods increased from 1.6% to 2% after 1772. The distinct results of the two aggregate industrial output indexes reflect the different weighting procedures of Hoffmann (1955) and Crafts and Harley (1992). In both total industry series there is an acceleration of trend growth rates, although this increase is much more pronounced in the Hoffmann series (from 1% to 3.4%) than in the Crafts-Harley series (from 0.7% to 1.7%). In addition, the number of bankruptcies peaked in the last decade of the 18th century, but then steadily declined after 1792. Since there was no significant change in the British bankruptcy laws until the 19th century, this structural break in the number of bankruptcies likely reveals that many “start-ups” of the emerging factory system were not successful. This evidence is consistent with the findings of Atkseon and Kehoe (1997), who show that major technological breakthroughs are often associated with large-scale experimentation by start-up firms leading to high bankruptcy rates.

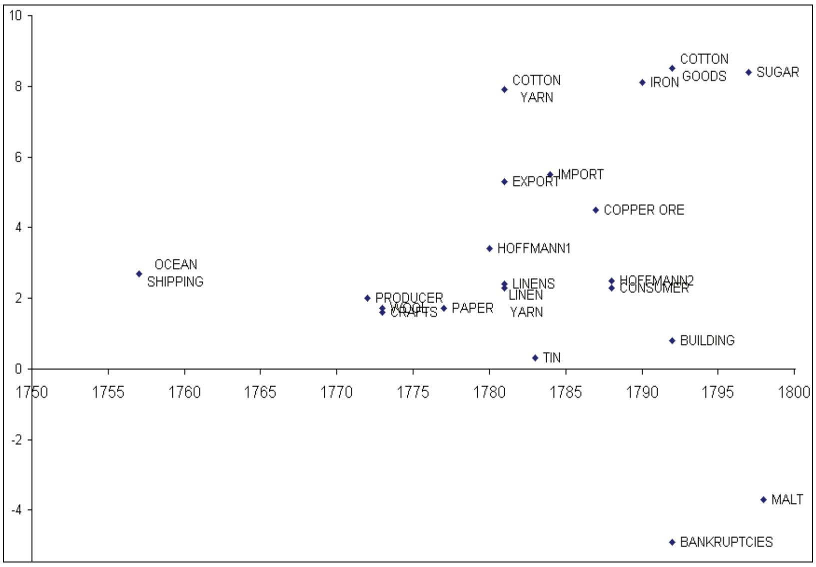
9 Pre- and post trend growth rates were found by estimating the following regression: $\log Y_t = \beta_0 + \beta_1 \text{Trend} + \varepsilon_t$, where Yt is series Y at time T, and Trend is a linear time trend. This simple method enables us to have an estimation of trend growth rates before and after the breaks occur. For an alternative approach that entails the estimation of smooth transition estimates of growth rates, see, for instance, Crafts and Mills (2004).

In terms of foreign trade, total imports underwent a structural break in 1784, after which trend growth accelerated from 1.3% to 5.5%, whereas total exports had a structural break in 1781 and trend growth increased from –0.03 % to 5.3%. In terms of patents, Sullivan (1989) previously found that there was a structural break in the number of patents in 1754. The Vogelsang tests for both the Hoffmann and the Dutton-MacLeod patent series suggest that there was another more prominent break during the early Industrial Revolution, which occurred in 1791. The trend growth rate in patents increased after the break from 3.5% to 5.5%. These breaks in patents cannot be explained by any change in the patent laws, because the British patent system was not substantially reformed until 1852 (although there was a minor reform in 1835). Hence, the breaks in patents are consistent with the signs of emerging capitalism (as MacLeod (1988) claimed) or by a rise in the rewards offered to inventors. That is, during the Industrial Revolution more people started using the formal system of invention, and the patent system became an institutionalized mechanism of protecting property rights[10]. Since the two "dynamic" sectors (cotton and iron) only provided 11 percent of the total number of patents, these findings suggest that either pervasive innovation or the signs of emerging capitalism were also taking place in the "traditional" sectors of the British economy.

All in all, most series analyzed exhibited significant structural breaks during the last quarter of the eighteenth century. Although the highest trend growth rates occurred in the cotton, iron, and sugar industries, there was also trend growth acceleration for the great majority of the other industries. Thus, the findings of the Vogelsang tests show that structural breaks were pervasive in the British industry, and hence growth was not solely "localized" in cotton and iron. In this context, cotton and iron seem to have been leading sectors in an environment of increasing dynamism all across the British industrial sectors, as suggested by Mokyr's (1990) survey of technological change and by the time series evidence presented by Greasley and Oxley (2000).

[10] Much innovation was also happening outside the formal patent system (Dutton 1984, MacLeod 1988, Mantoux 1961). Some inventors favored secrecy, others did not find it worthwhile protecting their innovations, and there were still others who found that "collective invention" was preferable to patent protection (Allen 1989). Reliable figures on this "informal" patent system would likely increase the trend growth acceleration in patents.

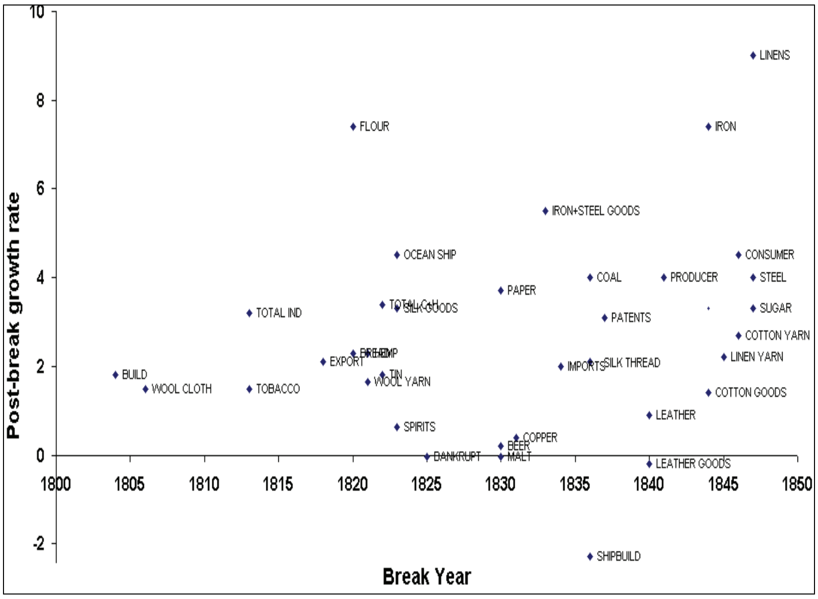
Post-Break Trend Growth Rates, 1750-1800



1800-1850

The results for the period 1800-1850 are summarized in Table 3. For most series, model I is again the preferred specification. Model II is the preferred specification for 9 series (malt, paper, sugar, producer goods, total industry Crafts-Harley and imports), whereas model III is the preferred specification for 3 series (malt, wool, and marriages). Second, the structural breaks occur throughout the whole 1800-1850 period, although they cluster slightly after the 1830s (figure 2). Third, contrary to the period 1750-1800, there is no clear picture regarding trend growth rates, since post-break growth accelerates in only 16 out of the 29 industries. In the remaining industries (except malt, leather good and shipbuilding), post-growth trend growth was still positive but lower than pre-break rates. This fact is consistent with the findings of Crafts and Mills (2004, 1994), suggesting that by mid-19th century there was a deceleration in some of the "leading-sector" industries of the Industrial Revolution, especially cotton. In contrast, both iron and steel had structural breaks in the late 1840s, after which there was a substantial acceleration in trend growth (iron from 4.8% to 7.4%, iron and steal products from 4 to 5.5%, and steel from 1% to 4%), attesting the increasing dynamism of these industries and the influence of the railways. The increasing competitiveness of British textiles is reflected by the sharp acceleration of trend growth rates in linens, rising from 1.9 to 9% after the structural break occurred.

Post-Break Trend Growth Rates, 1800-1850



Additionally, all aggregate indexes show an acceleration in trend growth during the period. Since the Napoleonic Wars contributed to a reduction of growth rates in the first decades of the 19th century (Williamson 1984), it is likely that some of the acceleration in aggregate growth might be attributable to the post-war recovery. In this case, a break could either be a symptom of the increasing dynamism of the economy or simply a resumption of the pre-war trend. Unfortunately, the empirical evidence is not completely clear in distinguishing the influence of these two forces.

In terms of the particular aggregate indexes, consumer goods had a break in 1846, which induced an acceleration of trend growth from 3% to 4.5%. The break in producer goods took place in 1807, and trend growth accelerated from 2.5% to 4%. Both aggregate industrial output indexes undergo structural breaks in the first decades of the 19th century, after which trend growth accelerates to around 3%. The similar magnitude of the structural breaks in trend growth for both indices is not surprising, since the differences in the weighting of the individual series in the aggregate index are less perceptible than in the 1750-1800 period. Other industries, such as flour production also experienced a substantial rise in their post-break trend growth rates (from 2 to 7.4%).

Table 3: SupWald values and Break years (1800-1850)

	Break Year	**Model**	**Sup-Wald**	**Sig-nific.**	**Pre-break trend growth**	**Post-break trend growth**
Beer	1830	I	66.58	1%	0.4	0.2
Breads and cakes	1820	I	25.61	1%*	2	2.3
Building	1804	I	686.8	1%	3.2	1.8
Coal	1836	I	31.33	5%	2.2	4
Copper	1831	I	50.46	1%	2.7	0.4
Cotton yarn	1846	I	86.85	1%	5.8	2.7
Cotton goods	1844	I	41.49	1%	5	1.4
Flour	1820	I	35.97	1%	2	7.4
Iron (Feinstein)	1844	I	42.36	1%	4.8	7.4
Iron and steel products	1833	II	120.23	1%	4	5.5
Pig Iron (Hoffmann)	1847	I	31.92	5%	5	3.3
Hemp prod-ucts	1821	I	23.13	1%*	-1.4	2.3
Leather	1840	I	28.53	10%	1.9	0.9
Leather goods	1840	I	31.22	10%	1.9	- 0.2
Linen yarn	1845	I	25.11	1%*	1.6	2.2
Linens	1847	III	14.38	1%	1.9	9
Malt	1830	III	35.49	5%	0.9	-0.04
Paper	1830	II	75.1	1%	2.5	3.7
Shipbuilding	1836	I	30.17	10%	1.7	-2.3
Ocean shipping	1823	I	41.68	1%	-1.5	4.5
Silk goods	1823	II	23.6	10%	1.5	3.3
Silk thread	1836	I	41.98	1%	5.7	2.1
Spirits	1823	I	32.43	5%	0.6	0.63
Steel	1847	I	29.35	10%	1	4
Sugar	1844	II	29.63	5%	4.6	3.3
Tin	1822	I	28.43	10%	1.4	1.8
Tobacco	1813	I	30.81	10%	0.8	1.5
Woolen cloth	1806	III	50.66	1%	2	1.5

Table 3 continued…

Woolen yarn	1821	II	34.18	1%	0.95	1.65
Aggregate indexes						
Consumer goods	1846	I	38.59	1%	3	4.5
Producer goods	1841	II	38.19	1%	2.5	4
Total Industry (Hoffmann)	1813	I	188.44	1%	2.3	3.2
Total Industry Crafts+Harley	1822	II	3.1	1%	2	3.4
Miscellaneous Variables						
Bankruptcies	1825	I	25.91	1%**	1.6	-0.05
Patents (Hoffmann)	1841	II	36.77	1%	2	3.2
Patents (MacLeod)	1837	I	30.31	5%	2.5	3.1
Exports	1818	I	31.4	5%	0.8	2.1
Imports	1834	II	36.8	1%	-0.02	2

* refers to stationary critical values

In turn, a small structural break in bankruptcies occurred in 1825, which probably can be explained by the financial crisis as well as by the minor changes in the British bankruptcy laws that occurred in that year[11]. Bankruptcies trend growth rates become slightly negative throughout the rest of the period. Patents underwent a structural break in 1837, after which trend growth rates slightly declined from 2.5% to 1.9%. This structural break might have been a consequence of the minor reform in patent law that took place in 1835 (Macleod 1988). The trade variables also show an acceleration in trend growth rates. Total exports had a structural break at the end of the Napoleonic Wars and trend growth accelerated from 0.8% to 2.1%. Total imports underwent a structural break in 1834, after which trend growth rates increased to 2%. For most of these series, trend growth rates decelerate after the structural break occurred.

[11] Since the Bubble Act of 1720 until 1861, most businesses in Britain operated under the principle of unlimited liability, which implied that "the failure of a company could be the ruin of its shareholders" (Weiss 1986, p. 33). Although seen as one of the cornerstones of British industrial success, the principle of unlimited liability complicated the raising of investment capital. Several changes in the bankruptcy laws (in 1810, 1825, 1861, and 1869) gradually removed the unlimited liability principle.

All in all, the findings of the Vogelsang structural break tests for the 1800-1850 confirm the increasing vitality of the British economy during the Industrial Revolution, corroborating the historical evidence that, by the early nineteenth century, the dynamism of the leading sectors was spreading across most industrial sectors. Although the influence of the Napoleonic Wars somewhat confuses matters, it is likely that most of the trend accelerations are related to the increasing dynamism of the British economy as previous empirical studies have found.

4. Concluding Remarks

The results from the Vogelsang structural breaks tests indicate that the Industrial Revolution was a period in which there were widespread structural changes and pervasive growth throughout the British industrial sector. These findings support the view that the Industrial Revolution can be characterized as a discontinuity in the process of British economic development, even though GDP growth during the period was sluggish by today's standards. In addition, the results of the Vogelsang tests show that during the early Industrial Revolution the highest post-break trend growth rates occurred in the iron and cotton industries as well as in the sugar industry. However, the breaks were not confined to the most dynamic sectors, and hence growth was not localized. These findings seem to provide additional support to the view[12] that the cotton and iron industries were the leading sectors of the British industrial sector, although they were by no means the only growth-enhancing industries of the period. All in all, the Vogelsang tests indicate that, during the early Industrial Revolution, structural changes were pervasive and the British economy became increasingly more dynamic.

References

Atkeson, A. and P. Kehoe (1997) "Industry evolution and transition: the role of information capital", *NBER Working Paper # 6005*.

Ben-David, Dan and D. H. Papell (1995) "The Great Wars, the Great Crash, and Steady State Growth", *Journal of Monetary Economics*, 36: 453-475.

Ben-David, Dan and D. H. Papell (1997) "International Trade and Structural Change", *Journal of International Economics*, 43: 513-523.

Berg, Maxine and Pat Hudson (1992) "Rehabilitating the Industrial Revolution", *The Economic History Review*, XLV: 24-50.

Berg, Maxine (1994) *The Age of Manufactures: Industry, Innovation and Work in Britain 1700-1820*, London: Routledge, 2nd edition.

[12] As espoused by the time-series evidence of Greasley and Oxley (2000, 1994).

Cairncross, A. K. And B. Weber (1956) “Fluctuations in Building in Great Britain, 1785-1849.

Clark, Gregory (2001) “The Secret History of the Industrial Revolution”, University of California Davis, mimeo.

Crafts, Nicholas F. R. (1985) *British Economic Growth during the Industrial Revolution*, Oxford: Oxford University Press.

Crafts, Nicholas F. R. and C. Knick Harley (1992), “Output Growth and the Industrial Revolution”, *Economic History Review,* 45 (4): 703-30.

Crafts, Nicholas F. R. and Terence C. Mills (1994) “The Industrial Revolution as a Macroeconomic Epoch”, *Economic History Review*, 47(4): 769-75.

Crafts, Nicholas F. R. and Terence C. Mills (2004) “Was 19th Century British Growth Steam Powered?: The Climateric Revisited”*, Explorations in Economic History*, 41: 156-171.

Deane, Phyllis and W. A. Cole (1969) *British Economic growth: 1688-1959*, Cambridge: Cambridge University Press.

Dutton, H. I. (1984) *The Patent System and Inventive Activity During the Industrial Revolution, 1750-1852*, Manchester: Manchester University Press.

Esteban, J. Cuenca (1994) “British Textile Prices, 1770-1831: Are British Growth Rates Worth Revising Once Again?”*, Economic History Review 47: 66-105.*

Feinstein, C. H. (1988) *Studies in capital formation in the United Kingdom: 1750-1920*, New York: Clarendon Press.

Goldstone, Jack (2002) “Efflorescences and Economic Growth in World History”, *Journal of World History* 13: 323-389.

Greasley, David and Les Oxley (1994) “Rehabilitation sustained: the industrial revolution as a macroeconomic epoch”, *Economic History Review*, XLVII(4): 760-68.

Greasley, D. and L. Oxley (2000) “British Industrialization, 1815-1860: A Disaggregate Time-Series Perspective”, *Explorations in Economic History*, 37(1): 98-119.

Harley, Knick (1982) “British Industrialization Before 1841: Evidence of Slower Growth During the Industrial Revolution”, *Journal of Economic History,* 42: 267-289

Harley, C. Knick and Nicholas F. R. Crafts (2000) “Simulating the Two Views of the Industrial Revolution”, *Journal of Economic History*, 60: 819-841.

Hoffmann, Walther (1955) *British Industry: 1700 to 1950*, New York: Kelley Books.

Mantoux, Paul (1961 [1927]) *The Industrial Revolution in the Eighteenth Century*, New York: Harper Torchbooks.

MacLeod, Christine (1988) *Inventing the Industrial Revolution: the English patent system, 1660-1800*, Cambridge, Cambridge University Press.

Mills, Terence C. and N. F. R. Crafts (1996) “Trend Growth in British Industrial Output, 1700-1913: A Reppraisal”, *Explorations in Economic History*, 33: 277-295.

Mitchell, B. R. (1988) *British Historical Statistics*, Cambridge University Press.

Mokyr, Joel (1990) *The Lever of Riches*, Oxford: Oxford University Press.

Ng, Serena and Pierre Perron (1995) “Unit Root Tests in ARMA Models with Data-Dependent Methods for the Selection of the Truncation Lag”, *Journal of the American Statistical Association*, 90: 268-281.

Perron, Pierre (1989) "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis", *Econometrica*, 57: 1361-1401.

Sullivan, R. (1989) "England's 'Age of Invention'", *Explorations in Economic History*, 21: 424-452.

Temin, P. (1997) "Two Views of the Industrial Revolution", *Journal of Economic History*, 57: 63-82.

Temin, P. (2000) "A Response to Harley and Crafts", *Journal of Economic History*, 60(3): 842-846.

Vogelsang, Timothy (1997) "Wald-type tests for Detecting Shifts in the Trend Function of a Dynamic Time Series", *Econometric Theory*, 13: 818-849.

Weiss, Barbara (1986) *The Hell of the English*, *London: Associated University Presses.*

Williamson, Jeffrey (1984) "Why was British Growth So Slow During the Industrial Revolution?", *Journal of Economic History*, 44(3): 687-712.