INNOVATION AND BRITISH REGIONS IN THE INTERWAR PERIOD

Work in progress, please do not quote

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Abstract

This paper investigates the regional distribution of innovation in Britain in the interwar period and contributes to the debate concerning the role played by corporate innovation in the relative decline of British industry. The paper is based on a novel dataset including more than 8,000 patents granted in the USA to British inventions in three benchmark years.

This dataset enables us to study for the first time the Revealed Technological Advantage (RTA) of British regions, thus identifying those technological fields where regions held an international technological advantage. The analysis shows that corporate innovation, government-sponsored research and pre-existent technological specialisation had an impact on the regional RTA and suggests regional and corporate technological lock-in, although to various degrees. These findings support the argument that corporations were responsible for a considerable share of innovation. However, only to a limited extent was such innovation taking place in the fastest growing sectors.

INTRODUCTION

Innovation, particularly in the form of development and adoption of new technologies, is central to long-term industrial competitiveness, economic growth and rising living standards. Britain in the interwar period constitutes a particularly interesting case study as it witnessed significant economic fluctuations and changing fortunes in its role as an international economic power.

Some researchers have pointed out that the British interwar economy was characterised by extremely high rates of unemployment, declining international trade and an industrial structure dominated by industries in secular decline. It has been often repeated that failings in industrial Research and Development explain, at least in part, the long-term decline of British industry (Landes, 1969; Mowery, 1986). Furthermore, it has been argued that British industry during the interwar period was locked in those sectors and fields of innovation that had once assured the growth of the British economy, but at a time when technological opportunities were rising more rapidly elsewhere (Walker, 1980; von Tunzelmann, 1982; Cantwell, 2000).

However, other studies have disputed this interpretation, pointing out that Britain witnessed significant and expanding R&D across its industries, impressive levels of corporate innovation, and the rapid expansion of ‘new’ assembly and science-based industries. Important innovations took place in both product and process technologies, with major changes in the scale, organisation and geography of industrial development (Alford, 1972; Sanderson, 1972; Edgerton and Horrocks, 1994).

Moreover, industrial R&D was been unfavourably compared with government-sponsored research by contemporary commentators. Their discussion concentrates mainly on the activities of the Department of Scientific and Industrial Research (henceforth DSIR) established in 1915 and government-sponsored research undertaken by the Co-operative Research Associations (henceforth CRAs), since 1918 (Sanderson, 1972; information about the CRAs are provided in table A.1 in the Appendix). Comparisons of the expenditures in R&D undertaken by the DSIR and by corporations, the latter based on reports from the Federation of the British Industry, clearly indicate that corporate expenditure in R&D was far greater (Sanderson, 1972; Edgerton and Horrocks, 1994).

However, corporate secrecy about their innovation activity, particularly as the DSIR and the CRAs disclosed information on their use of public finance, had led to the underestimation of the former (Sanderson, 1972, p. 107).

This paper contributes to the debates mentioned above. It analyses the comparative technological advantage of British regions and assesses the extent to which such an advantage was driven by the innovation activity of corporations, of government-sponsored research through the CRAs and by the pre-existent technological advantage within the geographical unit.

The research is based on a novel dataset including information on patents granted in the USA to British inventions throughout the interwar period. This paper is structured in four sections. The first section presents the dataset; it discusses the limitations of patent data as a proxy for innovation and how such limitations are addressed in the current work. The second section maps the distribution of innovation activity across British regions and studies their Revealed Technological Advantage (RTA). The third section provides an overview of the innovation activity of corporations. The fourth section assesses the extent to which regional RTAs are explained by the corporate innovative activity, government-sponsored research and by previous patterns of innovation. The final section draws the conclusions.

1. THE DATASET

This paper is based on a newly constructed dataset. It includes information on all patents granted in the USA to British inventions in the following benchmark years: 1918-19, 1925-26 and 1930-32. The total number of patents examined to date is 8,136. 10 patent records had to be excluded, as it was not possible to identify the location of the invention. We have classified each patent according to its technological field or sector (56 technological fields or sectors in total, see Table A.2 in the Appendix) and regions of invention, using the standard Nomenclature of Territorial Units for Statistics at level 2 of disaggregation (NUTS 2, see Table A.3 in the Appendix). Other information collected includes details of the innovation, whether it was an invention or an improvement, the name of the inventor, town and county of the invention, and, where provided, the corporate assignee name and location. 659 patent records displayed multiple inventors. Those patents have been geographically classified using the location of the first-named inventor. Inventors are not listed in alphabetical order in the patent record. Therefore, it seemed reasonable to assume that the first-named inventor was the main one.

As mentioned above patents have been classified in 56 technological fields. Three fields (8 = Disinfecting and preserving; 32 = Nuclear reactors; 40 = semiconductors) had fewer than 100 patents in the entire USPTO database for the benchmark years, thus suggesting these were small fields at the time. Therefore, patents in those three fields, both in the USPTO database and in the original dataset used in this paper, were incorporated into the most similar technological fields. The closest technological fields were identified using the 33 categories of technological activities and are, respectively, 10 = bleaching and dyeing; 31 = power plants; 41 = office equipment and data processing systems.

A long and distinguished literature has used patents to gain valuable insights into the pattern and direction of technological change. Yet, this proxy has its limitations.[1] Previous work has pointed out that not all inventions are patented and that the propensity to patent varies across industries and in time. Moser (2005) investigated the varying propensity to patent across industries by looking at the share of exhibits at the Great Exhibition of 1851 that received English patents. Her findings show that industries such as food processing and chemicals had a low propensity to patent, whereas engineering was the industry with the highest propensity by far. Seminal work by Scherer (1983) has analysed the patents to expenditure on R&D ratio, using data from the late twentieth century. His findings show that 'stone, clay and glass processing' is the industry with the highest propensity to patent, followed by 'petroleum' and 'chemicals'. Our analysis takes into account the varying propensity to patent across industries, by using the Revealed Technological Advantage (RTA) index (Cantwell, 1989; Soete, 1980). As explained below, the RTA is normalised for inter-industry - in addition to inter-country - differences in the propensity to patent.

[1] For a discussion of patents as an indicator of invention and innovation see Cantwell (2006).

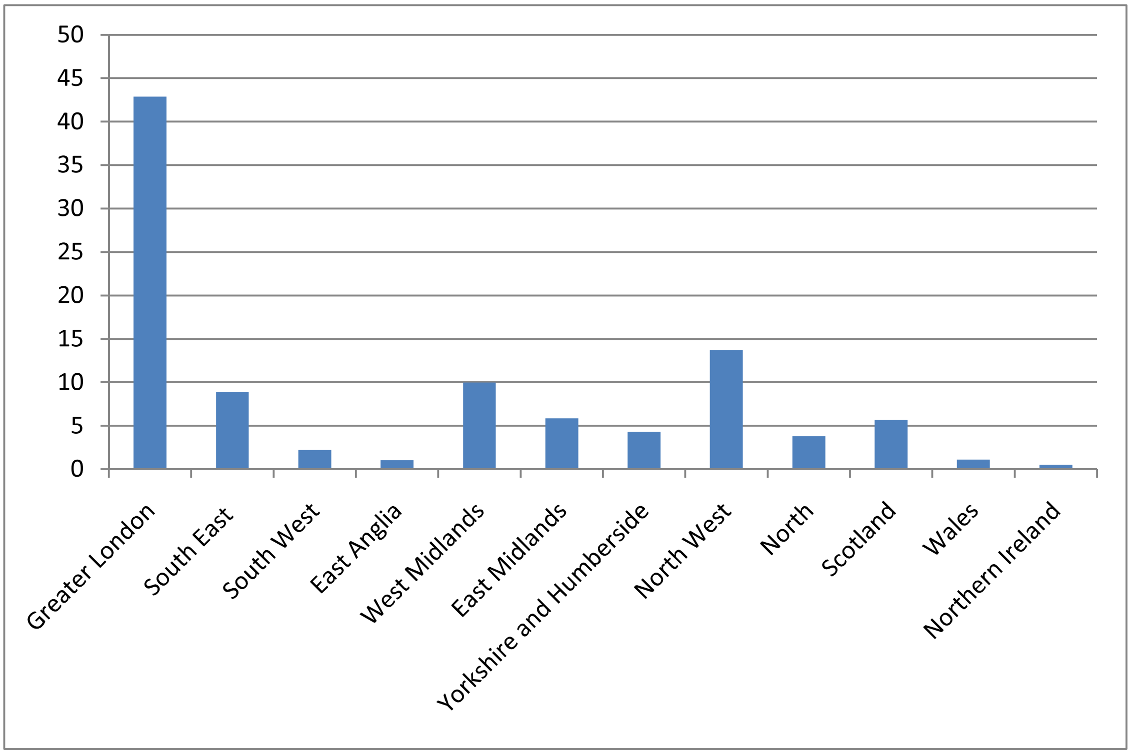
Another shortcoming of patents is the difficulty of accounting for the varying economic and technological importance of the patented invention (Griliches, 1990; Schankerman and Pakes, 1986). This dataset addresses this shortcoming by taking into account only British patents that were granted in the USA. British inventors and firms would have been much less likely to face the additional costs of registering their invention in the USA if their invention had not been of economic value to the inventor or the assignee. Moreover, such inventions went through an additional screening procedure in order to be patented in the USA. Therefore, the double patenting, at home and abroad, can be interpreted as an indicator of the economic importance of such patents.

A frequently mentioned limitation of patents as a proxy for technical advances is that not all inventions are patented. However, surveys based on large samples of firms demonstrate that patents follow the distribution of innovation (Pavitt, Robson and Townsend, 1985). The large number of patents included in this dataset ameliorates the suitability of this proxy, as the large sample reduces biases due to accidental factors and to the possible inclusion of patents with little or no economic value. While each patent cannot be interpreted as an invention, the concentration of patents within a certain technological sector indicates technological opportunities in that sector. The rate of growth of patenting across different fields in each period serves as an indicator of the areas in which technological opportunities were greatest at that time (Cantwell, 1991; Cantwell and Barrera, 1996; Cantwell and Andersen, 1996).

2. INNOVATION IN THE BRITISH REGIONS

This section addresses the first objective of this paper, i.e. to analyse the technological comparative advantage of British regions. The graph below displays the regional distribution of patents in the dataset. As the largest group of patents (3,600) was awarded in 1930-32 the overview in the graph below is biased towards those years.

Graph 1: Percentage of USPTO patents by regions and Greater London, 1918-32 (benchmark years)



Source: original dataset – see text.

The geography of innovation reflects the geography of the fastest growing industries at that time. It is clear that the high concentration of innovative activity was in the Greater London area, followed at a considerable distance by the North West, West Midlands and the South East. The four regions together accounted for 75.5% of all patents in this period.

Greater London and the South East came to dominate both craft industries such as 'clothing and footwear' and assembly consumer goods industries. Moreover London began to attract new service industries such as the film industry that became more London-centred and the radio industry with the establishment of the British Broadcasting Corporation (BBC) in 1922. The other region to attract a substantial base of new assembly goods industries was the West Midlands, with its marked specialisation in the 'other metal goods' industry and its related industries such as 'metal manufacture' and 'vehicles' (Scott, 2007).

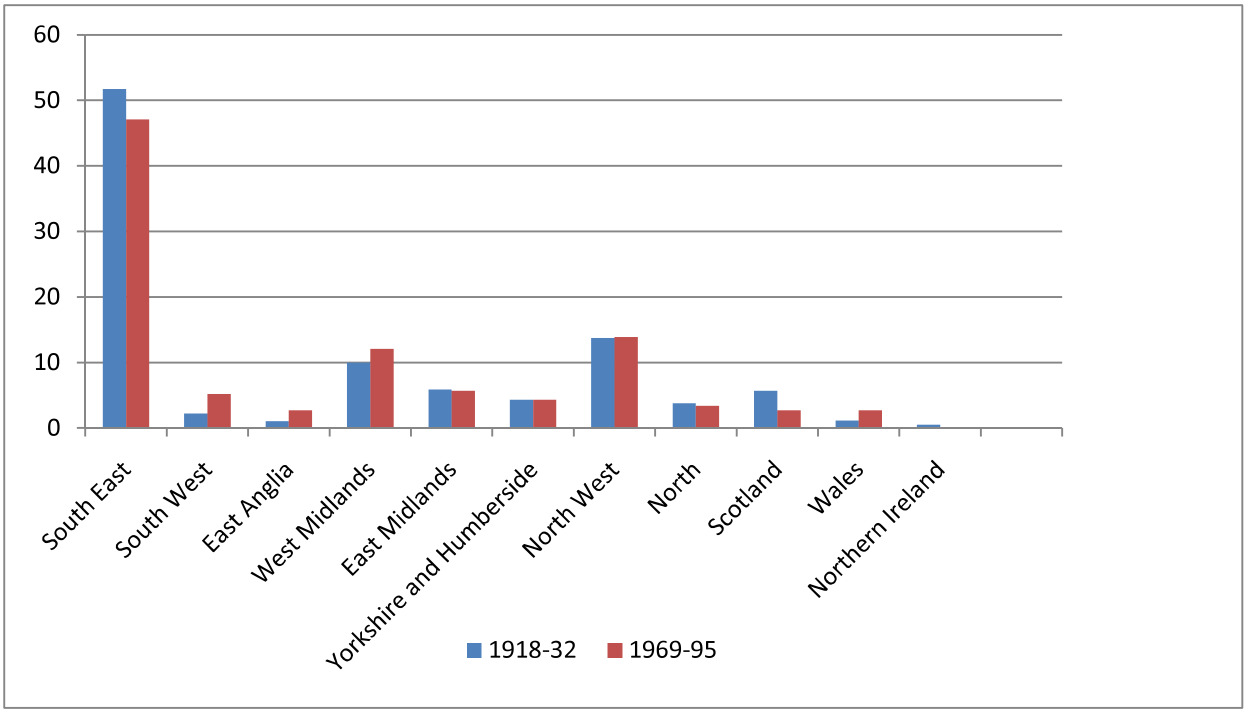
The North West was part of the 'industrial heartland' together with Yorkshire & Humberside and the East Midlands. These regions had inherited a strong specialisation in mature industries such as textiles, and to a much lesser extent in mechanical engineering and chemicals, providing textile machinery and chemical compounds for the textile processes.

The remaining regions can be divided into two broad types: the Northern region, Wales and Scotland, which had inherited an industrial structure based around the declining staple industries, i.e. coal and iron, steel and shipbuilding; and East Anglia and the South West, which were largely agricultural (Scott, 2007).

This distribution of patents in Graph 1 is similar to the one observed in the period 1969-1995 in Graph 2 below. In particular the regions with the highest concentration of patents are the same. It is interesting to note that the relative weight of the South East, including Greater London, decreased in 1969-95 compared with 1918-32, which is likely to be related to the increasing weight of the service industry. However, the South East outweighs by far any other region in both periods, thus suggesting that the region as such has developed a comparative advantage. Dynamic regions attract the development of a broad range of industries, due not only to the variety of industries already existent, but also to infrastructure, financial facilities, readily available markets for products and services as well as labour force. A similar pattern is also displayed by dynamic regions in other countries, e.g. Lombardy and Piedmont in Italy, Île de France, and North Rhine-Westphalia, Bavaria and other regions in Germany (Cantwell and Iammarino, 2003).

The distinction between a regional comparative advantage and an industry-related technological advantage seems important, as the former might lead to growth in the long term whereas the latter might generate technological lock-in and only short-term growth.

Graph 2: Percentage of USPTO Patents by UK regions, 1918-1935 (benchmark years) and 1969-1995



Source: original dataset – see text and Cantwell and Iammarino, 2000.

Note: South East includes Greater London. The 1969-95 figures do not separate the two.

The geographical distribution of patents displayed in Graphs 1 and 2 might be affected by differences in the patenting propensity of different industries. Thus, if a region is specialised in an industry with a low propensity to patent such as 'food and tobacco', fewer patents will be registered there as compared with a region specialised in an industry with a high propensity to patent such as manufacturing machinery. In order to address this bias, the following analysis uses the Revealed Technological Advantage (RTA) index (Cantwell, 1989, p. 19):

Equation 1:

$$RTA_{ij} = (P_{ij} / P_{wj}) / (\Sigma_j P_{ij} / \Sigma_j P_{wj})$$

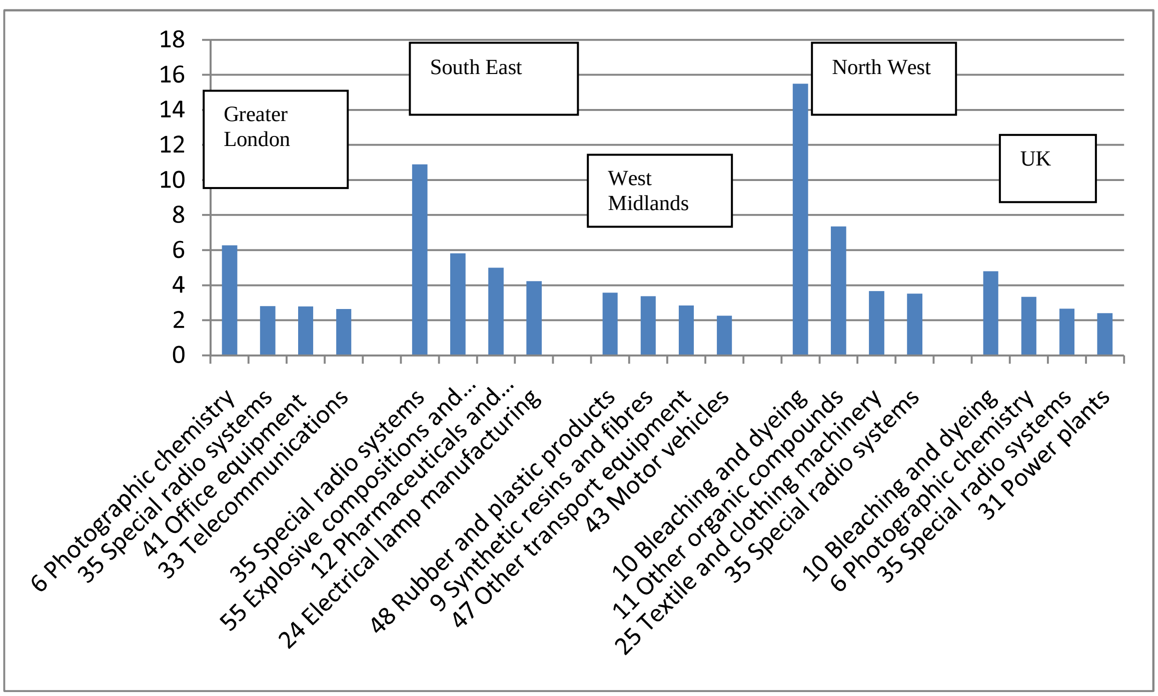
Where:

i = 1, 2, 3, 4, 5; J= 1,….., 56; P_{ij} = the number of patents of region i in sector j; P_{wj} = the number of world patents in the same sector

The index assesses the performance of the region in a certain sector in the international context. The ‘world’ figure in the formula above is given by the total number of USPTO patents, granted to innovations generated in any country of the world, in the same sector and year. The RTA index varies around unity. Therefore, an RTA value greater than one suggests a comparative technological advantage; an RTA value below one indicates a position of relative disadvantage.

Graph 3 below displays the RTA index for the four regions with the largest concentration of patents: Greater London, the North West, the West Midlands and the South East, and the UK. Moreover, for the sake of clarity, for each region only the four sectors with the highest values of the RTA index have been reported in the graph. The RTA index values for all sectors have been included in table A.1 in the Appendix.

Graph 3: RTA index: selected regions and the UK, by sectors, benchmark years (1918-1935)



Source: original dataset – see text.

Finding a precise correspondence between technological groups and industrial sectors can be difficult. The 56 technological groups are comprehensive and they include 399 technological sectors. For instance the technological group 35 includes such sectors as ‘Telecommunications’, ‘Communications, directive radio wave system and devices’ and ‘Communications, radio wave antennas’. In addition to this, the technological sector and group in which a patent is classified might be rather different from the sector of the patenting or assignee firm. A firm producing electrical equipment might have some of its patents classified in metallurgical processes, metal products and specialised machinery (Cantwell and Barrera, 1998).

The overview in Graph 3 indicates an overall comparative advantage in the Chemical industry. Each of the four regions, and the country as a whole, has at least one of its main four comparative advantages in a technological field related to the Chemical industry, i.e. ’Photographic chemistry’ (6), ’Synthetic resins and fibres’ (9), ’Bleaching and dyeing’ (10), ’Other organic compounds’ (11) and ’Pharmaceuticals and biotechnology’ (12). This is not surprising considering that Chemicals was a growing sector in British manufacturing and that ‘Bleaching and dyeing’ is related to the manufacturing sector ‘Textile and clothing’, which, although declining, was the major manufacturing sector of the British economy in the early 1920s (Broadberry, 1997).

Such a comparative advantage is particularly evident in the North West, related in particular to the textile chemical industry, consistently with the region’s industrial specialisation. A number of patents in the dataset were assigned to British Dyestuffs Corporation Limited and Imperial Chemical Industries (ICI), with Manchester – the headquarters of the United Alkali Company - as the location of invention. The Celanese Corporation of America is also mentioned as one of the assignees particularly for patents related to the treatment of artificial silk made from cellulose acetate. Such patents refer to inventions developed in the research facilities of the British Celanese Corporation in Cheshire. It is not surprising to note that when such inventions were patented in the USA the assignee was the American branch of the corporation.

It is particularly interesting that corporations such as ICI and British Celanese emerge from this regional overview as they were at the forefront of chemical research and established significant research facilities. By the beginning of the 1930s ICI’s research capabilities had become comparable with Du Pont's, with the British corporation spending 2.8% of its total sales on R&D as compared with the 2.4% of its American counterpart (Chandler, 1990; Mowery and Rosenberg, 1989).

The West Midlands displays a comparative technological advantage in 'Motor vehicles' (43) and 'Transport equipment' (47), consistent with its manufacturing specialisation. Courtaulds Ltd is mentioned often as an assignee of patents in 'Synthetic resins and fibres' (9), as the corporation held a lead position in rayon production in Britain, thus competing with British Celanese, and in the USA, competing with Du Pont and other European firms (Chandler, 1990, p. 272; Coleman, 1969, pp. 244-313). The technological comparative advantage in 'Plastic products' (49) is clearly related to the comparative advantage in motor vehicles. One of the most recurrent names among the assignees of such patents is the Dunlop Rubber Company, which established the main British production facility of automobile tyres in Birmingham at the beginning of the twentieth century and by the First World War had set up a research and development organisation (Chandler, 1990, p. 269; Jones, 1984).

Greater London displays a particularly marked comparative advantage in 'Photographic chemistry' (6). Patents in this technological group are related to the film industry, and refer to the invention and improvement of 'multicolour cinematograph material' and 'colour photography' with companies such as Agfa Ansco Corporation as corporate assignees. Agfa's patents date from the 1930s, in other words after the formation of I.G. Farben in 1925, when Agfa agreed not to expand its dye line and to concentrate on photochemicals (Chandler, 1990, p. 480)**.**

Patents in the technological field 'Special radio systems' (35) are related to the improvements and applications of the wireless telegraph. Some of these patents have Guglielmo Marconi himself as inventor and the Marconi Wireless Telegraph Company of America as assignee. In 1919, the American branch of the Marconi Company was purchased by General Electric in a move instigated by the U.S. Navy, which was reluctant to depend on a foreign company. The British Marconi Company had to accept GE's acquisition of its stock in the Marconi Company of America and all the Marconi patent rights for the USA becoming the property of the Radio Corporation of America (RCA), which GE established to take over the Marconi assets (Reich, 1977).

Greater London displays a comparative advantage also in the technological field ‘Semiconductors’ (40). These patents refer to systems for alternating electric current, therefore it seems plausible to relate them to the importance of electrical engineering, one of the fastest growing industries, in terms of new plant establishment, in Greater London in the interwar period (Scott, 2007, pp.152-159). These patents are also related to the railways as the systems for alternating electric current were applied to railway signals and the assignee was the Union Switch and Signal Company, Pennsylvania (USA).

The technological group ‘Special radio systems’ (35) is also the marked comparative advantage of the South East, with patents for radio signalling system and wireless telegraph and telephone aerials. The comparative advantage in ’Pharmaceuticals and biotechnology’ (12) is clearly related to the importance of the chemical industry in the South East, in addition to the North West. These patents refer to processes such as the preparation of sterilising agents and germicides and the fermentation of cellulosic material, and have assignees such as the United Water Softeners Limited, London. The South East also displays a comparative technological advantage in ‘Electrical lamp manufacturing’ (24) and ‘Explosive components’ (55), with both groups representing traditional specialisations of the chemicals and electrical industries.

3. THE ROLE OF CORPORATIONS

This section focuses on corporate innovation and evaluates its importance for the regional and national technological advantage.

As mentioned in the Introduction, inadequate and insufficient R&D has been considered an important explanatory factor in the declining shares of British export and lower relative rates of productivity growth. Landes (2003) and Mowery and Rosenberg (1989) stress that the research intensity of the British manufacturing sector was well below that of its American counterpart. Scientific research within British firms was hampered by various factors, such as the delayed managerial revolution and the scarcity of trained scientists and managers, and the government-sponsored research associations could not be a substitute for in-house research (Mowery 1986; Elbaum and Lazonick, 1986).

However, a considerable stream of studies has shown that significant R&D was taking place within British firms between the wars (Sanderson, 1972; Hannah, 1976; Edgerton and Horrocks, 1994). The growth of large firms was stimulating expenditure on R&D and new products such as television, plastics and electric lamps were the results of research conducted in corporate laboratories (Hannah, 1976, pp. 113-114). Sanderson (1972) stressed the rapid scientific development in British industry between the wars and the increasing number of research teams and laboratories, particularly in chemicals, engineering, food and electrical engineering.

We contribute to this debate by looking at the numbers and percentages of patents assigned to corporations (corporate assignees) and they will be referred to as corporate patents. Such patents include not only inventions generated within the corporation, either through corporately financed research and development and employees regularly engaged in it or by engineers and scientists employed in operating departments; but it includes also patent rights assigned by independents to firms (Schmookler, 1966, pp. 25-27).

Table 1: Regions ranked by rates of corporate innovation

	1918-19	1925-26	1930-32	1918-32	Absolute Values
East Midlands	38.9	52.5	69.8	59.3	283
North	42.1	45.5	68.4	54.5	168
North West	24.6	41.6	68.5	49.9	557
East Anglia	38.1	36.4	59.5	48.2	41
West Midlands	33.9	40.5	55.4	45.2	366
Greater London	35.7	36.9	47.6	41.2	1,437
Scotland	30	33.3	43.6	36.4	168
Northern Ireland	18.8	0	66.7	34.9	15
South-West	17	34	41.3	32.8	59
South-East	20.3	26.8	43.2	32.5	234
Yorkshire and Humberside	20	30.3	41	30.9	108
Wales	14.6	16	20	16.5	15
UK	31.1	37.1	52.9	42.5	3,451
USA	28.3 [a]	35.3	49.0	41.8	116,657
British corporations' share of UK total	72.1	66.3	58.7	64.8	2,235

Keys: a= 1921
Sources: original dataset – see text and *Historical statistics of the United States: earliest times to the present*, Vol. 3. *Economic structure and performance*, pp. 426-429.

Corporate innovation taking place in the UK is broadly in line with its American counterpart, in terms of shares of corporate patents and their rising trend – although the magnitude of patenting activity in the two countries is very different. However, British corporations account only for part of such innovation activity. The remaining share is represented by inventions made in Britain and assigned to foreign corporations, mainly American, or their British subsidiaries. The inventions developed in the research facilities of the British Celanese Corporation in Cheshire and assigned to the Celanese Corporation of America are case in point. This facet might be particularly evident in our dataset as it includes patents granted in the USA to British inventions.

It is clear that the ranking of regions in Table 1 does not reflect the ranking of regions by share of patents. Of the four regions with the highest patent share discussed in the previous section, the South East stands out for its low share of corporate assignees, due in particular to low values in 1918-19 and 1925-26.

The region leading the ranking in Table 1 is the East Midlands. The corporations appearing most frequently as assignees are the above-mentioned American Cellulose and Chemical Manufacturing Company Limited / Celanese Corporation of America, United Shoe Machinery Corporation and Rolls-Royce Limited. The first company, which changed its name to Celanese Corporation in 1927, presents a number of patents in the technological field ‘Bleaching and dyeing’ (10), but also in ‘Textile and clothing machinery’ (25) and ‘Other general industrial equipment’ (29).

The Rolls-Royce Limited aircraft engine factory in Derbyshire produced inventions in ‘Metallurgical process’ (13), ‘Chemical and allied equipment’ (16), ‘Internal combustion engines’ (42) and ‘Other instruments and controls’ (53). Some of such patents have Frederick Henry Royce himself as inventor.

The United Shoe Machinery Corporation was for most of the 20th century the world’s largest manufacturer of footwear machinery and materials. It is the single most important inventor in the East Midlands, in our dataset. Its patents are mainly concentrated in ‘Textile and clothing machinery’ (25) and ‘Other specialized machinery’ (28), but some are also classified as ‘Chemical and allied equipment’ (16) and ‘Metal working equipment’ (17).

The North displays a large share of corporate patents. The most recurrent corporate assignees in the North are two engineering companies that merged in 1968, A. Reyrolle & Company Ltd and Charles Parsons. Reyrolle patented in sectors such as ‘Other electrical communication systems’ (34), ‘Electrical devices and systems’ (38) and ‘Other general electrical equipment’ (39). Charles Parsons took its name from the founder and inventor of the steam turbine. The patents in the dataset have Charles Parsons himself as inventor and are mainly in technological fields such as ‘Other general industrial equipment’ (29), ‘Illumination devices’ (37) and ‘Other general electrical equipment’

(39). Other corporate assignees in the region were Electrical Improvement Limited and the engineering firms Vickers and Armstrong, which merged in 1927. One of the major corporate assignees in the region was ICI, for inventions developed in the facilities in Stockton- and Norton-on-Tees.

It seems important to pay attention to the fields in which corporate innovation was taking place in order to assess whether this occurred in the new industries that emerged in the interwar years, i.e. automobiles and plastics, electrical appliances, electronics and aeronautics, or in the declining staple industries of the nineteenth century, such as textiles, coal, steel, shipbuilding, electricity and heavy chemicals (Rostow, 1978; von Tunzelmann, 1982).

Table 2. Corporate patents in the top 15 technological fields by absolute values and percentages

Technological Sectors		Absolute values	Technological Sectors		Percentages
29	Other general industrial equipment	324	35	Special radio systems	90.9
53	Other instruments and controls	220	33	Telecommunications	80.6
25	Textile and clothing machinery	216	10	Bleaching and dyeing (disinfecting and preserving incl.)	73.2
38	Electrical devices and systems	211	11	Other organic compounds	71.3
56	Other manufacturing and non-industrial	189	55	Explosive compositions and charges	64.3
16	Chemical and allied equipment	184	6	Photographic chemistry	63.9
14	Miscellaneous metal products	153	38	Electrical devices and systems	63.4
39	Other general electrical equipment	149	24	Electrical lamp manufacturing	60.0
33	Telecommunications	145	9	Synthetic resins and fibres	58.8
11	Other organic compounds	144	30	Mechanical calculators and typewriters	57.7
20	Assembly and material handling equipment	134	34	Other electrical communication system	57.7
17	Metal working equipment	122	39	Other general electrical equipment	56.4
28	Other specialized machinery	122	2	Distillation processes	54.5
26	Printing and publishing machinery	88	51	Coal and petroleum products	53.7
10	Bleaching and dyeing (disinfecting and preserving incl.)	71	41	Office equipment and data processing systems (Semiconductors incl.)	53.4

Source: Table A.4 in the Appendix.

The picture emerging from Table 2 is somewhat mixed, with high shares of corporate innovation in emerging technological fields such as ‘Telecommunications’ and ‘Other organic compounds’ and ‘Electrical devices and systems’, but also in traditional ones such as ‘Bleaching and dyeing’, ‘Chemical and allied equipment’ and ‘Textile and clothing machinery’. Moreover, low shares of corporate assignees are displayed in other emerging sectors such as ‘Internal combustion engines’, ‘Motor vehicles’ and ‘Aircraft’ (see table A.4 in the Appendix).

In order to assess more accurately whether corporate innovation in the UK was higher in those sectors with high technological opportunities we have calculated the growth rates of patents in the 56 technological sectors using all the patents registered in the USPTO and then calculated the coefficients of correlation displayed in Table 3 below.

Table 3. Coefficient of Correlation between corporate patenting (CP) and growth rates (Growth) in technological fields

18-19 CP / 18-19 Growth	25-26 CP / 25-26 Growth	25-26 CP / 22-25 Growth	30-32 CP / 30-32 Growth	30-32 CP / 27-30 Growth
0.54***	-0.03	-0.16	0.27*	0.01

Sources: Cantwell/Spadavecchia database – see text.

Note= *** p<0.01, ** p<0.05, * p<0.1

It is clear that there is a certain degree of correlation between corporate patenting and technological opportunities. However, this is considerably stronger at the beginning of the interwar period.

The mixed evidence provided in this section suggests a certain degree of technological lock-in. This argument is consistent with the theoretical notion that technological change is a cumulative, incremental and differentiated process (Pavitt, 1987). Firstly, technological and technical changes within a firm are cumulative processes in the sense that firms will try to improve and diversify their technology building upon their existing stock of their technological knowledge. Firms can convert knowledge deriving from other firms, markets and public knowledge into new technology by dipping into their knowledge base (Pavitt, 1987). Secondly, innovation develops incrementally, so that firms tend to move gradually between related sectors. Thirdly innovation is differentiated at the firm level and the location level as the technological development followed by a firm or a location is distinctive and characterised by elements that are specific to that firm or location. These prepositions suggest that the pattern of technological advantage of firms, regions and countries will, once established, remain relatively stable over time. In other words that innovation is liable to 'lock in' to a particular industrial pattern or configuration in any location, and that this pattern is likely to change only gradually over time (Cantwell, 1989 and 1991).

4. AN ECONOMETRIC ANALISYS OF THE REVEALED TECHNOLOGICAL ADVANTAGE

This section provides an econometric assessment of the factors affecting the Revealed Technological Advantage (RTA) displayed by the four regions and Britain as a whole in the latest benchmark years, i.e. 1930-32. We test the lock-in argument, at regional level, by assessing the impact of the pre-existing technological specialisation of the region as expressed by the RTA for previous benchmark periods, i.e. 1918-19 and 1925-26 (see equation 2 below). Furthermore we assess whether the regional RTA is associated with opportunities in the technological fields through the variable Growth, i.e. the growth rate of patents in each technological field.

In the econometric analysis the RTA has been used in its adjusted form (see equation 3). The RTA has a lower bound of zero but in principle no upper bound, therefore it can produce a positively skewed distribution (Laursen, 2000). Over a sufficiently large number of patents the occurrence of values above two is infrequent, and therefore the RTA closely resembles a normal distribution, in cases where the number of observations is limited the RTA tends to be skewed. We have therefore used the adjusted version shown in equation 3. The adjusted RTA is inherently symmetrical as it varies around zero (when RTA = 1) with a lower bound of -1 and an upper bound of +1 (Cantwell, 1989; Cantwell and Vertova, 2004).

We test the impact of corporate innovation on the regional RTA by looking at two facets: the relative weight of corporate innovation expressed through the ratio of patents with a corporate assignee in each technological field and region (variable CP in equation 2); the concentration or dispersion of innovation across corporations within each technological field and region, expressed through the Herfindahl-Hirschman (variable HHI in equation 2). The Herfindahl-Hirschman Index (see equation 4) would be equal to one if all patents in each technological field and region were owned by the same corporation; it would take the value of 1/n if such patents were equally distributed across corporations. This facet is clearly related to the 1942 Schumpeterian hypothesis according to which oligopolistic firms are in a better position to innovate due to financial resources and the appropriability of returns.

Equation 2 also assesses the importance of government-sponsored research for the technological advantage of the region. The impact of government-sponsored research has been assessed through the variable CRAs, i.e. the logarithmic value of the government grant received by each CRA as reported in Table A.1, column 6, in the Appendix. The number of CRAs located in the South East, North West and Midlands was clearly insufficient to construct a variable. The CRAs variable is used only in the regressions for Greater London and Great Britain.

The economic activity of the region has been expressed through the variable Emp defined as in equation 5, so as to take into account the various levels of labour intensity of each industry. In the case of Great Britain it was not possible to account for different degrees of labour intensity in various industries and thus a simple ratio has been used.

Equation 2:

$$\mathrm{AdjRTA}_{ij30-32} = \alpha + \beta_1 \mathrm{AdjRTA}_{ij18-19} + \beta_2 \mathrm{AdjRTA}_{ij25-26} + \beta_3 \mathrm{Gr}_{wj18-25} + \beta_4 \mathrm{Gr}_{wj26-32} + \beta_5 \mathrm{CP}_{ij18-26} + \\ + \beta_6 \mathrm{CP}_{ij26-32} + \beta_7 \mathrm{HHI}_{18-32} + \beta_8 \mathrm{CRAs} + \beta_9 \mathrm{Emp}_{ij21} + \beta_{10} \mathrm{Emp}_{ij31}$$

where: i = 1,2,3,4,5; j = 1,…, 56; w = world; CP = corporate innovation; HHI = Herfindahl-Hirschman Index, see equation (4); Gr = rate of growth in technological fields; CRAs= Co-operative Research Associations; Emp = Employment by industry adjusted by labour intensity in Britain.

Equation 3:

$$\mathrm{AdjRTA}_{\mathrm{ijt}} = (\mathrm{RTA}_{\mathrm{ijt}} - 1)/(\mathrm{RTA}_{\mathrm{ijt}} + 1)$$

Where:

i = 1, 2, 3, 4, 5; j=1,….., 56; t= 1918-19; 1925-26; 1930-32; RTA = see equation (1)

Equation 4: Herfindahl-Hirschman Index

$$HHI_{ij18-32} = \sum_{c=1}^{N} (P_{cij18-32} / P_{ij18-32})^2$$

Where: C= corporation; P=patents; i = 1, 2, 3, 4, 5; j= 1,….., 56;

Equation 5:

$$\mathrm{Emp}_{\mathrm{ijt}} = (\mathrm{Emp}_{\mathrm{ijt}} / \mathrm{Emp}_{\mathrm{GBjt}})/(\Sigma_{\mathrm{j}}\mathrm{Emp}_{\mathrm{ijt}} / \Sigma_{\mathrm{j}}\mathrm{Emp}_{\mathrm{GBjt}})$$

Where: Emp= employment; i = 1, 2, 3, 4, 5; j = 1,….., 56; t = 1921; 1931; GB= Great Britain.

Table 4. Linear Regressions: Regional Adj RTA $_{30\text{-}32}$ (robust standard errors in parentheses)

	Greater London	South East	West Midlands	North West	UK
Adj RTA $_{18\text{-}19}$	-0.027	0.043	0.149	0.278*	0.0581
	(0.155)	(0.197)	(0.134)	(0.148)	(0.141)
Adj RTA $_{25\text{-}26}$	0.655***	0.114	0.335**	0.365***	0.888***
	(0.184)	(0.151)	(0.148)	(0.124)	(0.186)
Growth $_{18\text{-}25}$	0.001	0.024*	-0.009	0.008	0.010
	(0.006)	(0.013)	(0.010)	(0.011)	(0.009)
CP $_{26\text{-}32}$	0.003**	0.002	0.006***	0.006***	0.001
	(0.001)	(0.001)	(0.002)	(0.001)	(0.003)
HHI	0.646	-0.487*	-0.271	0.874**	0.582**
	(0.579)	(0.266)	(0.225)	(0.374)	(0.257)
CRAs	0.029*				0.021
	(0.017)				(0.014)
Emp $_{21}$ [a]		0.480*	-0.389	0.041	
		(0.269)	(0.353)	(0.326)	
Constant		-0.480*	-0.314	-0.316*	-0.094
		(0.256)	(0.202)	(0.161)	(0.083)
Observations	53	49	49	49	53
R^2	0.57	0.251	0.519	0.638	0.54
F *(p-value)*	12.33 (*0.000*)	3.13 (*0.006*)	11.56 (*0.000*)	12.75 (*0.000*)	12.07 (*0.000*)

Notes: *** p<0.01, ** p<0.05, * p<0.1; variables not significant for any geographical units have not been displayed.
a= the variables Emp_{21} and Emp_{31} showed evidence of colinearity in the case of Greater London and Great Britain. For those geographical units a new employment variable Emp $_{(21+31)}$ was

computed adding up the values of the 1921 and 1931 Censuses. The variable is not displayed as it was not significant for either geographical unit.

The positive and significant association with the RTA in 1925-26 indicates continuity in the technological specialisations of the country and all the regions, except for the South East. Existing specialisation, rather than technological opportunities, in later years in particular ($Growth_{25-26}$), contribute to the regional specialisation in 1930-32. The argument of the British technological lock-in seems evident in the case of the North West, where the technological advantage in 1930-32 is positively associated also with the RTA in the first benchmark period. There is also evidence of the positive and significant role played by corporations either through the relative weight of corporate innovation as a whole or through an oligopolistic position held by some - once again with the exception of the South East.

The North West presents enhanced evidence of the argument of technological lock-in and of the importance of corporate innovation. This is not surprising considering that the marked technological specialisations in ‘Bleaching and dyeing’, ‘Other organic compounds’ and ‘Textile and clothing machinery’ displayed by the North West in Graph 3 run through the three benchmark years. Moreover, ‘Bleaching and dyeing’ and ‘Other organic compounds’ in particular display a high Herfindahl-Hirschman index value, as a large part of the patents was owned by ICI. ‘Textile and clothing machinery’ was a technological specialisation since the first benchmark period, but the ownership of patents is dispersed, thus producing a low Herfindahl-Hirschman index value. The remaining North-Western specialisation in Graph 3, i.e. ‘Special radio systems’, emerged in the region, and even more so in the South East only in the latest benchmark period and was dominated by the Radio Corporation of America. In the previous two benchmark years this technological specialisation had been located in Greater London.

The results displayed by the South East seem to tell a different story. The technological advantage observed in the South East in the latest benchmark period (1930-32) is not significantly associated with the technological advantage of the region in previous benchmark years. Two of the major advantages displayed by the South East in Graph 3, namely ‘Special radio systems’ and ‘Electrical lamp manufacturing’ appear only in the latest benchmark period. The latter was present only in the North West in previous benchmark years and the former in Greater London, as already mentioned. Therefore, we find no evidence of technological lock-in within the region, but the South East seems to receive technological specialisations developed previously in other regions, hence the positive and significant association with ‘old’ technological opportunities (variable Gr_{18-25}) and ‘old’ economic activities (variable Emp_{21}). Moreover, the concentration of innovation activity within a small number of firms has a significant and negative impact, thus suggesting that the South East is characterised by ‘diffused’ innovation (Richter and Streb, 2009).

Finally, government-sponsored research has a positive and significant impact on the technological advantage of Greater London, where the laboratories were mainly concentrated, but its impact is not significant in the case of Great Britain as a whole.

PROVISIONAL CONCLUSIONS

This preliminary paper has provided an overview of the regional distribution of innovation in Britain in the interwar years. This work is the first to perform such an analysis and has highlighted a regional ranking rather similar to the one observed for the 1969-95 period. In both periods Greater London and the South East combined, the North West and the West Midlands witnessed a high concentration of innovations. Greater London and the South East combined outweigh by far all other regions in the interwar and in the post-WWII period. This indicates a comparative advantage related to the region itself, rather than to specific industries and technological fields.

The novel dataset used in this paper indicates that a considerable share of British innovation was taking place within corporations. The percentage of corporate patents in Britain is in line with the American counterpart. However, a considerable share of such innovation activity took place within British branches of American multinationals, particularly in the 1930-32 benchmark period.

Corporate innovation was a significant factor in the technological advantage of regions, however corporations kept abreast with the growing technological opportunities only to a limited extent. This coupled with the fact that the technological advantage of the country and the regions – with the exception of the South East – was significantly associated with the technological advantage in previous benchmark years, portrays the overall picture of a country whose innovation was not concentrated in fields with growing technological opportunities.

Appendix

Table A.1 Co-operative Research Associations (CRAs)

	Location [a]	Date of formation	Beginning of grant-earning period	Number of completed years of work (31 July 1932)	Total value of gran (31 July 1932) £
British Photographic Research Association	Central London	05/05/1918	15/05/1918	12 (31 July 1930)	26,110
British Scientific Instrument Research Association	Central London	23/05/1918	01/07/1918	14	123,341
British Research Association for the Woollen and Worsted industries	Leeds	26/09/1918	01/10/1918	13	77,143
British Portland Cement Research Association	Central London	09/11/1918			
Research Association of British Motor and Allied Manufacturers	Central London	13/03/1919	01/04/1920	10 [b]	25,711
British Boot, Shoe and Allied Trades Research Association	Central London	01/05/1919	01/01/1919	13	10,762
British Sugar Research Association	Central London	28/05/1919	(Licence issued by BoT on28/03/1919)		[c]
British Cotton Industry Research Association	Manchester	07/06/1919	01/07/1919	13	136,040
British Iron Manufacturers Research Association	Manchester	03/07/1919	(Licence issued by BoT on 03/07/1919)	5	[d]
Glass Research Association	Central London	08/08/1919			58,600
Linen Industry Research Association	Belfast	10/09/1919	01/10/1919	12	64,241

Research Association of British Rubber and Tyre Manufacturers	Croydon, London	30/09/1919	01/01/1920	12	34,750 [e]
British Association of Research for Cocoa, Chocolate, Sugar Confectionery and Jam Trades	Central London	04/12/1919	01/10/1919	12	26,792
British Non-Ferrous Metals Research Association	Central London	05/12/1919	01/01/1920	12	66,694
British Refractories Research Association	Stoke-on-Trent	15/03/1920	01/07/1920	12	23,280
Scottish Shale Oil Scientific and Industrial Research Association	Glasgow	25/03/1920	01/04/1920	12	7,500 [f]
British Launderers' Research Association	Hendon	19/07/1920	01/10/1920	11	27,815
British Leather Trades' Research Association	Central London	27/07/1920	01/10/1920	11	27,544
British Cutlery Research Association	Sheffield	17/09/1920	01/01/1921	11	10,829[g]
British Electrical and Allied Industries Research Association	Central London	22/09/1920	01/10/1920	11	94,501
British Motor Cycle and Cycle Car Research Association	Coventry	16/10/1920	01/01/1921	9 [h]	9,050
British Silk Research Association	Leeds	17/11/1920	01/01/1921	11	15,228
British Music Industries Research Association	Holloway, London	24/11/1920			
British Cast Iron Research Association	Birmingham	24/05/1921	01/07/1921	11	39,207
Research Association of British Flour Millers	St. Albans	01/07/1923	01/07/1923	9	22,582
British Colliery Owners' Research Association	Central London	29/12/1924	(Licence issued by BoT on 29/december/1924)	7	[i]

British Food Manufacturers' Research Association	Holloway, London	01/07/1925	01/07/1925	7	7,291
Research Association of British Paint, Colour and Varnish Manufacturers	Teddington	01/07/1926	01/07/1926	6	23,843
British Iron and Steel Federation (Iron and Steel Industrial Research Council)	Central London	01/01/1929	01/07/1929	3	18,166
Printing Industry Research Association	Central London	21/11/1930	(Licence issued by the BoT on 21 November 1930)	1	[j]
Institution of Automobile Engineers (Research and Standardisation Committee)[k]	Chiswick	01/07/1931	01/07/1931	1	2,500

Sources: I. Varcoe (1981) "Co-operative Research Associations in British Industry, 1918-34", *Minerva*, Vol. 19/3, pp. 433-463; *Report of the Committee of the Privy Council for Scientific and Industrial Research*, HMSO, various years.

a: Refers to permanent laboratories acquired in most cases after the date of formation. Offices were sometimes elsewhere, usually in Central London. The Shale Oil Research Association, the Colliery Owners' Research Association, the Iron and Steel Foundation (Industrial Research Council) and the Printing Industry Research Association did not have central laboratories; in these cases the location of the association's headquarters is reported.
b: Grant aid to the Research Association of British Motor and Allied Manufacturers ceased at the close of the year ended 31 March 1927; *Report* (1931).
c: The British Empire Sugar Research Association operated until February, 1926, on a limited scale only, assisted by grant aid from the interest of the Million Fund; its operations are at present completely suspended (*Report*, 1927, p. 6)
d: The operations of The British Iron Manufacturers Research Association were suspended in 1924 and, it is understood, have not been resumed up to July 1932.
e: This figure does not include an advance of £2,500 made to the Research Association of British Rubber Manufacturers for the year ended 31 December, 1929.
f: This grant was paid in respect of the first five years of the period of operations; the Association has since continued operations without further grant aid.
g: This figure does not include advances, amounting to £6,000, made to the British Cutlery Research Association during the three years ended 31 December, 1928, which are repayable from royalties (see also *Report*, 1933, p. 98).

h: grant aid to the British Motor Cycle and Cycle Car Research Association ceased at the close of the year ended 31 December 1927; *Report* (1932).

i: British Colliery Owners' Research Association is not in receipt of grant aid from the Department.

j: The Printing Industry Research Association is not in receipt of grant aid from the Department.

k: The Research and Standardisation Committee of the Institution of Automobile Engineers took over the research work of the Research Association of British Motor and Allied Manufacturers as from 1 July 1931, and that of the British Motor Cycle and Cycle Car Research Association as from 1 January, 1932.

Table A.2: The complete RTA index (56 technological sectors) for the four regions with the highest concentration of patents and for Britain, 1918-1932 (benchmark years)

	Technological Fields	Greater London	South East	West Midlands	North West	UK	USPTO
1	Food and tobacco products	1.91	0.64	0.38	1.52	1.26	2,048
2	Distillation processes	2.10	1.69	1.50		1.65	260
3	Inorganic chemicals	1.89	1.28	0.57	1.78	1.56	2,070
4	Agricultural chemicals	0.90			1.40	0.96	203
5	Chemical processes	1.43	0.81	1.62	1.31	1.30	4,336
6	Photographic chemistry	6.28	4.19	0.00	2.03	3.34	420
7	Cleaning agents and other compositions	1.59	0.98	1.02	1.48	1.22	2,688
9	Synthetic resins and fibres	0.96	0.84	3.37	2.71	1.27	1,045
10 (8 incl)	Bleaching and dyeing (disinfecting and preserving incl.)	2.08	0.00	0.50	15.50	4.81	787
11	Other organic compounds	1.33	1.18	1.28	7.36	2.35	3,355
12	Pharmaceuticals and biotechnology	1.38	4.99	0.00	0.36	1.13	793
13	Metallurgical processes	0.92	1.02	1.74	0.88	1.02	5,164
14	Miscellaneous metal products	0.51	0.60	0.83	0.32	0.52	41,971
15	Food, drink and tobacco equipment	0.52	0.56	0.50	0.91	0.52	1,564
16	Chemical and allied equipment	1.32	1.15	1.15	1.39	1.27	14,917
17	Metal working equipment	0.67	0.84	1.10	0.78	0.88	15,244
18	Paper making apparatus	1.06	0.10	0.47	0.47	0.83	4,204

19	Building material processing equipment	0.63	0.54	1.11	1.26	0.81	2,467
20	Assembly and material handling equipment	0.93	0.91	1.13	0.85	0.98	12,063
21	Agricultural equipment	0.06	0.18	0.32	0.12	0.14	4,851
22	Other construction and excavating equipment	0.32	0.31	0.27	0.20	0.43	1,441
23	Mining equipment	0.48	0.42	0.37	0.00	0.39	2,097
24	Electrical lamp manufacturing	1.75	4.23	0.00	2.73	1.87	104
25	Textile and clothing machinery	0.38	0.58	0.67	3.67	1.82	9,882
26	Printing and publishing machinery	2.13	1.72	0.19	1.73	1.63	4,097
27	Woodworking tools and machinery	0.20	0.00	0.00	0.62	0.26	917
28	Other specialized machinery	0.59	0.72	0.72	0.66	0.71	18,930
29	Other general industrial equipment	1.04	0.86	0.79	0.92	1.04	32,245
30	Mechanical calculators and typewriters	0.63	0.47	0.41	0.45	0.54	1,890
31 (incl 32)	Power plants (nuclear reactors incl)	1.88	2.27	1.21	2.93	2.41	969
33	Telecommunications	2.65	0.71	0.09	2.34	1.61	4,364
34	Other electrical communication system	1.41	0.91	0.00	1.17	1.05	966
35	Special radio systems	2.82	10.90	0.00	3.51	2.66	323
36	Image and sound equipment	2.04	3.41	0.56	0.73	1.43	3,483

37	Illumination devices	1.01	0.77	0.92	0.39	0.75	5,127
38	Electrical devices and systems	0.96	1.44	1.18	1.47	1.03	12,563
39	Other general electrical equipment	0.99	1.22	1.36	1.19	1.06	9,744
41 (incl 40)	Office equipment and data processing systems (Semiconductors incl)	2.78	3.29	1.86	0.58	1.94	1,470
42	Internal combustion engines	1.82	1.78	1.58	1.15	1.59	4,454
43	Motor vehicles	0.52	1.33	2.25	0.17	0.77	3,297
44	Aircraft	1.86	3.05	0.57	0.31	1.49	2,744
45	Ships and marine propulsion	2.11	1.04	2.04	1.61	2.03	2,110
46	Railways and railway equipment	0.66	0.44	0.15	0.42	0.48	8,026
47	Other transport equipment	0.66	0.66	2.85	0.80	0.91	6,045
48	Textiles, clothing and leather	0.58	0.87	0.60	0.37	0.64	4,559
49	Rubber and plastic products	1.00	0.83	3.58	0.36	1.07	3,169
50	Non-metallic mineral products	0.79	1.05	0.83	0.68	0.79	7,968
51	Coal and petroleum products	1.17	2.21	0.00	0.48	0.89	1,789
52	Photographic equipment	1.79	1.88	0.33	0.73	1.10	1,169
53	Other instruments and controls	1.31	1.70	1.55	0.80	1.22	20,969
54	Wood products	0.48	1.35	0.24	0.09	0.38	3,254
55	Explosive compositions and charges	1.20	5.82	0.00	0.00	2.40	227

56	Other manufacturing and non-industrial	1.51	0.69	1.08	0.50	1.07	16,007
	Total patents	3,484	720	810	1,117	8,126	316,849

Source: Cantwell/Spadavecchia original dataset – see text.

Table A.3: British Regions, NUTS 2

NORTH	103010000
YORKSHIRE AND HUMBERSIDE	103020000
EAST MIDLANDS	103030000
EAST ANGLIA	103040000
SOUTH EAST	103050000
SOUTH WEST	103060000
WEST MIDLANDS	103070000
NORTH WEST	103080000
WALES	103090000
SCOTLAND	103100000
NORTHERN IRELAND	103110000

Table A.4: Patents with a corporate assignee by technological field (percentage)

	Technological Fields	1918-19	1925-26	1930-32	1918-32	1918-32 Absolute Values
1	Food and tobacco products	0.0	31.6	36.4	27.3	18
2	Distillation processes	0.0	80.0	50.0	54.5	6
3	Inorganic chemicals	40.7	52.0	54.8	49.4	41
4	Agricultural chemicals	33.3	0.0		20.0	1
5	Chemical processes	17.9	32.6	57.7	42.1	61
6	Photographic chemistry	37.5	20.0	82.6	63.9	23
7	Cleaning agents and other compositions	14.3	37.5	60.9	46.4	39
9	Synthetic resins and fibres	33.3	44.4	68.2	58.8	20
10 (8 incl)	Bleaching and dyeing (disinfecting and preserving incl.)	42.9	50.0	80.3	73.2	71
11	Other organic compounds	40.0	50.0	78.8	71.3	144
12	Pharmaceuticals and biotechnology	0.0	40.0	58.3	47.8	11
13	Metallurgical processes	31.9	30.3	47.3	37.8	51
14	Miscellaneous metal products	17.5	26.9	34.7	27.2	153
15	Food, drink and tobacco equipment		12.5	53.8	38.1	8
16	Chemical and allied equipment	19.8	34.8	48.4	37.9	184
17	Metal working equipment	24.6	37.8	46.2	35.4	122
18	Paper making apparatus	9.1	37.0	49.0	40.4	36
19	Building material processing equipment	33.3	35.7	57.1	47.1	24
20	Assembly and material handling equipment	23.6	43.0	55.2	44.2	134
21	Agricultural equipment	0.0	42.9	0.0	17.6	3
22	Other construction and excavating	0.0	28.6	0.0	12.5	2

	equipment					
23	Mining equipment	0.0	42.9	77.8	47.6	10
24	Electrical lamp manufacturing		0.0	75.0	60.0	3
25	Textile and clothing machinery	41.9	37.0	54.8	46.8	216
26	Printing and publishing machinery	32.0	51.2	59.4	51.5	88
27	Woodworking tools and machinery	0.0	33.3	100.0	33.3	2
28	Other specialized machinery	18.4	32.5	46.4	35.5	122
29	Other general industrial equipment	33.3	36.6	41.8	37.9	324
30	Mechanical calculators and typewriters	50.0	33.3	81.8	57.7	15
31 (incl 32)	Power plants (nuclear reactors incl)	54.2	16.7	66.7	51.7	31
33	Telecommunications	59.1	63.4	90.6	80.6	145
34	Other electrical communication system	16.7	57.1	76.9	57.7	15
35	Special radio systems	75.0	100.0	93.8	90.9	20
36	Image and sound equipment	27.8	39.6	56.5	46.1	59
37	Illumination devices	31.3	33.3	52.7	43.9	43
38	Electrical devices and systems	39.6	48.5	77.4	63.4	211
39	Other general electrical equipment	51.2	56.3	61.6	56.4	149
41 (incl 40)	Office equipment and data processing systems (Semiconductors incl)	0.0	43.8	61.5	53.4	39
42	Internal combustion engines	28.4	28.3	33.3	29.7	54
43	Motor vehicles	25.0	30.8	32.1	29.2	19
44	Aircraft	30.4	53.3	36.4	36.2	38
45	Ships and marine propulsion	20.0	35.3	31.6	26.4	29
46	Railways and railway equipment	21.4	33.3	52.6	37.4	37
47	Other transport equipment	31.1	23.7	33.3	29.8	42

48	Textiles, clothing and leather	22.2	26.9	48.4	34.7	26
49	Rubber and plastic products	30.0	37.9	60.5	46.0	40
50	Non-metallic mineral products	20.0	25.6	53.6	35.8	58
51	Coal and petroleum products	30.0	45.0	90.9	53.7	22
52	Photographic equipment	25.0	60.0	63.6	48.5	16
53	Other instruments and controls	30.3	30.0	38.5	33.6	220
54	Wood products	18.2	8.3	55.6	25.0	8
55	Explosive compositions and charges	70.0	100.0	33.3	64.3	9
56	Other manufacturing and non-industrial	53.6	33.3	36.4	43.1	189
	Total	31.1	37.1	52.9	42.5	3,451

Note: empty cells indicate the absence of patents; 0.0 indicates the absence of patents with a corporate assignee.

Source: Cantwell/Spadavecchia original dataset – see text.

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