

**The origins of the Anglo-American 'productivity gap' in electronics: the
British and American interwar radio equipment industriesⁱ**

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Introduction

The interwar radio equipment industry is generally characterised as one of the most poorly-performing British manufacturing sectors relative to the United States, largely owing to the pioneering productivity analysis of L. Rostas.ⁱⁱ As an archetypal 'new' industry, involving complex assembly operations and 'high-tech' components, the poor apparent productivity record of this sector reinforces evidence from another much more extensively studied industry, motor vehicles, that Britain suffered fundamental productivity weaknesses in dynamic, technologically-driven manufacturing operations.ⁱⁱⁱ However, in contrast to motor vehicles economic historians have paid relatively little attention to this sector and studies from the early post-war period remain the standard works for both Britain and America.^{iv}

This paper first re-assesses Britain's relative labour productivity, showing that, when 1935 is taken as the bench-mark for both countries, the Anglo-American productivity gap is substantially less than that identified by Rostas (who compared US productivity in 1939 with British data for 1935), but is nevertheless considerable. The causes of Britain's poorer productivity are then examined. Differences in the socio-legal environments of the two countries are shown to have played a crucial role in allowing key players in the British industry to derive much higher monopoly rents than their American counterparts. This, in turn, had the unanticipated effect of initiating a path-dependent process of technical change in favour of product innovations which reduced manufacturers' royalty liabilities but increased their direct production costs.

Comparative productivity estimates

Rostas' estimates - that American radio equipment output per employee, and per operative, in 1939 were 3.41 and 3.48 times the respective British figures for 1935 - are commonly used as productivity bench-marks for the sector.^v Unusually poor comparative

British radio productivity is at odds with contemporary evidence regarding the sector's strong product performance. For example, a January 1934 U.S. Department of Commerce report noted that American sets had no obvious superiority in design to their U.K. counterparts, while new circuits were introduced in both countries almost simultaneously.^{vi} Nor, as demonstrated below, was this an industry characterised by strong economies of scale, giving American firms a major advantage owing to their larger market size. The extent of the productivity gap identified by Rostas appears, instead, to be an artefact of his methodology.

Rostas' comparison is based on gross output per person, for the British wireless equipment, and wireless valves and electric lamp, sectors, with the American radio, radio tubes and phonograph sector [hereafter radio etc. sector]. Adjustments are made for duplications owing to products which are inputs to other firms' production; output by firms in the sector of items classified under other sectors; to deduct output in the U.S. 'phonographs, records, and other phonographic products' sub-sector; and to add U.S. production of radio parts by communications equipment firms.^{vii} Employment is then adjusted to account for estimates of the ratios of operatives to total employees. However, as these are similar for the two countries and their potential margin of error is greater than the country differences, the productivity estimates below are all per employee, rather than per operative.^{viii}

Rostas appreciated that (in addition to the different Census categorisations of radio equipment), there were also problems arising from differences in the composition of production. A large part of U.S. output consisted of 'midget' sets, which had no counterpart in the U.K., while U.S. 'tubes' were simpler and much less differentiated in design than British 'valves'.^{ix} This greatly complicated the task of estimating a purchasing power parity (PPP) exchange rate, though he ascertained from trade sources that the:

comparative price of a broadly identical table receiver was \$35 in the U.S. in 1939, and £12 12s in the U.K. in 1935; for consoles the comparison would be one of \$50 with £18 18s. These comparisons indicate exchange rates in terms of radio products of \$2.80 and \$2.65 to the £, or an average of \$2.75. For valves no direct comparison is available, but \$2.75 is probably a likely exchange rate for both valves and other radio products. By accepting this exchange rate... the assumption is made that the average U.S. set is about one-sixth lower in quality and the average U.S. valve about one-third lower in quality than the U.K. product. This is not unreasonable, as... U.S. output contains a high proportion of midget sets... the U.S. valve is of a simpler construction and more valves are needed per unit as initial equipment.^x

The major problem with this procedure is that (unlike the majority of his sectoral studies) radio was a dynamic industry subject to rapid productivity increases, unit cost reductions, and quality improvements. Thus, while Rostas' comparison is accurate for the years given, it greatly exaggerates relative productivity differences in 1935. In 1939 the dollar price of an average American radio was only 61.5 percent of its 1935 price.^{xi} The ratio of small radios to total output had increased markedly over these years, though this had been accompanied by a significant increase in quality (stimulated by the fact that the industry mainly served replacement demand). Thus the average American radio of 1939 was probably of at least equivalent quality to its 1935 counterpart. The modified exchange rate, reflecting the unit price change in American radios from 1935-39, would be \$4.47. Meanwhile American labour productivity had risen substantially over 1935-39, as Rostas acknowledged.^{xii}

Using the more limited U.S. Census data for 1935 allows direct comparison of Anglo-American radio productivity for the same bench-mark year. Using net, rather than gross, output per worker makes it unnecessary to account for duplication of valves and components,

as the data represent value added net of materials and components inputs (together with fuel and the cost of out-sourced work). The 1935 data do not allow for adjustments for non-radio sector production by radio firms, or the production of radio components by communications equipment firms; though these factors do not appear to significantly distort the comparison.^{xiii} Table 1 provides an estimate of net output per worker for the U.K. and U.S. radio industries, using Rostas' PPP rate, modified to take account of changes in unit radio prices over 1935-39, as noted above. Comparisons are also shown using the exchange rate and a general U.K./U.S. PPP estimate derived from Angus Maddison's international GDP data. U.S./U.K. relative productivity in 1935 is estimated at 2.16, compared to Rostas' 1939/35 estimate of 3.41. This compares reasonably well with the average productivity gap found by Rostas, for the 31 manufacturing sectors he examined.^{xiv}

[Table 1 near here]

The exchange rate gives a significantly lower productivity gap, which is substantially further reduced using the general PPP estimate, as, while overall British prices were significantly lower than the nominal exchange rate,^{xv} radio equipment prices were substantially higher. This, in turn, was the product of a British socio-legal system which enabled certain sections of the industry to derive monopoly rents and thereby bias technical change towards a higher cost path. Before discussing this, we examine other potential explanations of America's superior productivity, such as more rapid household diffusion and scale economies.

A comparison of the British and American industries

Table 2 shows estimates of radio production in the U.S.A. and U.K., together with figures for the household diffusion of receivers in the two countries. U.K. production data cover only 1930-35 and 1937, while the 1930-32 estimates are based on Radio Manufacturers Association (RMA) data, which exclude non-member firms and thus under-estimate total output. Nevertheless, it is clear that British output lagged behind the United States, even relative to their respective populations. U.K. radio licence statistics suggest that this reflected slower British household diffusion. However, as there was substantial evasion of license payments, these data under-estimate diffusion relative to U.S. data on radio ownership. In July 1925 it was estimated that while there were 1.4 million British radio licenses, some three million sets were in use.^{xvi} Market research surveys of 1935 and 1939 found similar proportions of UK households with radios but no licences.^{xvii} When unlicensed radios are added to the U.K. total, Britain is shown to have significantly faster household diffusion. This appears counter-intuitive, given America's much higher real wages. However, there were strong regional variations in U.S. radio ownership, from over 90 per cent in many north-eastern states in 1937 to under 50 per cent in several southern states.^{xviii}

[Table 2 near here]

The relatively high diffusion of radios compared to other electrical appliances, particularly in Britain, reflected the fact that unlike labour-saving consumer durables, radios provided a highly valued entertainment service, lacking very close substitutes, and demand was thus price and income inelastic.^{xix} As D.S. Landes noted, radio constituted a 'counter-status luxury', utility varying inversely with income (as higher income groups have more substitutes for its entertainment services).^{xx} Despite relatively high British radio prices, the 1935 and 1939 radio ownership surveys found that diffusion rates to working-class households were only around three percentage points below those for all households.^{xxi}

Domestic sales dominated production; American exports represented only 10 per cent of receiver output (606,784 units in 1935), while British exports amounted to only 56,056 units.^{xxiii} Of greater importance in boosting American sales was their much higher production of car radios (1,125,000 units in 1935) and – more importantly - of cheap ‘midget’ sets, which stimulated both sales of supplementary sets to households and the diffusion of radios in commercial buildings such as hotels and offices. Midget sets were primarily responsible for the 25 per cent growth in U.S. radio production over 1935-37, when the market for main household sets was already saturated and demand for auto radios and exported sets experienced only modest absolute growth (290,000 units collectively).^{xxiii}

Labour productivity was relatively low in both countries, relative to electrical engineering and all manufacturing. In 1935 average employment for establishments with 11 or more workers, in the British radio equipment industry (excluding valves) was 345.6, compared to 105.4 for all factory trades. Yet net output per employee, £211, was below the average for all factory trades (£229) or all electrical engineering (£231).^{xxiv} Similarly, average U.S. employment in the radio etc. sector was 228.6 persons in 1935, compared to 141.2 for electrical machinery and 42.9 for all manufacturing. Yet net output per wage-earner was \$2,172 for radio etc., compared with \$3,055 for electrical machinery and \$2,575 for all manufacturing.^{xxv}

Britain had more large plants (in terms of employment); only 45 per cent of 1939 U.S. radio sector employment was in plants of over 1,000 people, compared to 66 per cent for British wireless apparatus plants in 1935 (while 54 per cent of British radio valve and electric lamp employment was in plants of over 750 workers).^{xxvi} Yet there is little evidence of scale economies in either country. In 1935 net output per employee for U.K. radio equipment (excluding valve) plants of over 1,000 workers (£216) was only marginally above that for all plants (£211) and below the level for plants with 25-49 or 200-299 workers.^{xxvii} Meanwhile

average net output per worker for radio valves and electric lamps was higher than that for the largest plants (with 750 or more employees). Net output per wage-earner for U.S. radio etc. plants was actually highest for micro-enterprises with an average employment of 4.2 persons and, although value added per worker for the largest plants by output (with an average employment of 1,872.9 workers) was above the sector average (£3,342 compared to £2,988), the other three output categories with over 100 workers per plant all had below-average net output per worker.^{xxviii}

Large American radio producers enjoyed much greater absolute output than their British counterparts, but there were no substantial difference relative to the size of their respective industries, as shown in Table 3. These data – for the U.K. in 1938^{xxix} and the USA in 1940, are the earliest available comprehensive estimates; though the US figures appear to be broadly similar to those for the 1930s.^{xxx} In both countries the largest firm accounted for around 15 per cent of total output; the top five for a little over half, and the top ten for almost three quarters.

[Table 3 near here]

The lack of clear scale economies was strongly linked to the speculative nature of the industry; the bulk of annual sales represented new models, demand for which was not easily predictable. Richard Haigh, English manager of the Gramophone Co (part of EMI), reported that their major difficulty with radio production was estimating demand.^{xxxi} Similarly, British manufacturer V.Z. de Ferranti characterised radio as, ‘a highly speculative business... based on trying to guess what the public taste and demand will be.’^{xxxii} American producers encountered similar difficulties; a 1931 report described them being, ‘at the mercy of style changes and new inventions that overnight might convert a warehouse supply of stored radios

into stock out of date and worthless in the eyes of the buying public, that will be satisfied with nothing but the latest model.^{xxxiii}

Annual model changes also contributed to highly seasonal production, particularly in Britain, where factories began developing new models from around July, then built up stocks to meet anticipated demand following the annual London 'Radiolympia' show. Seasonal labour (mainly women and juveniles) was worked intensively until sales fell in the new year, then laid off.^{xxxiv} Seasonality in the American industry was markedly weaker (though still substantial), as shown in Figure 1. U.S. data are based on employment, while the U.K. data show the number of valves produced (for set-makers and for the retail trade; valves only for new sets showed even greater seasonality). Employment is likely to have lower seasonality than production – owing to over-time and short-time working. However, this is not believed to substantially distort the data, as sales during the early months of each year largely comprised stocks sold off at bargain prices rather than new production.

[Figure 1 near here]

The coefficient of variation of monthly production in Britain was around 0.5-0.6 (and 0.6-0.7 for radio receivers), compared to 0.3-0.4 in the United States during the late 1920s and 0.1-0.2 in the late 1930s. One reason for Britain's stronger seasonality was the central importance of the Radio Manufacturers Association (RMA) Radiolympia exhibition. Unlike the main annual show for the British motor vehicle industry (another highly seasonal trade), which was timed to stimulate sales in the slack season, Radiolympia was held at the start of the new season (in September until 1931 and in the second half of August thereafter).^{xxxv} US radio exhibitions were also originally held in the autumn, though the first [US] Radio Manufacturers Association 'Radio Trade Exposition', in June 1927, broke this pattern, establishing June as the start of the season.^{xxxvi}

Leading British radio manufacturer Frank Murphy boycotted Radiolympia, arguing that it was too late in the year, and launched new sets in the spring or summer, supported by publicity that summer purchases reduced seasonal unemployment.^{xxxvii} However, as a trade commentator noted, this strategy was 'courageous', as new models had to compete with the bargain offers of competitors selling-off stock at cut prices.^{xxxviii} The RMA comprised dozens of set-makers, whose collective agreement would be required for a move in the timing of Radiolympia. Each firm would have to modify their annual cycle of new model production and associated planning and, in an industry largely shielded from imports, many set-makers felt little incentive to support a change which might benefit larger competitors more than themselves.

The hypothesis that Radiolympia accentuated an autumn demand peak is corroborated by Figure 1, which shows a much sharper spike in production over September-November in Britain; compared to America's markedly longer season, with a clear up-turn evident from June. Yet in both countries manufacturers were reluctant to invest in expensive machinery, much of which would lie idle during the slack season.^{xxxix} They therefore opted for relatively labour-intensive techniques, using high proportions of un/semi-skilled, often female, labour. In October 1939 some 50.78 per cent of manufacturing employees in the U.S. radio etc. sector were female, while in 1935 females comprised 49.09 of average annual employment in British 'radio apparatus, telecommunications equipment, gramophones, and electric lamp' production (though given that seasonal workers were predominately female, the figure for October would be significantly higher).^{xl}

Figure 1 also indicates that U.S. seasonal fluctuations had become less severe between the late 1920s and late 1930s. This was largely due to America's development of products with a different pattern of seasonality to the household's prime receiver. Car radios experienced rapid growth, comprising 13.57 per cent of US radio unit sales in 1938, but only

1.04 per cent of British sales in 1939 (mainly due to much lower car-ownership).^{xli} Yet of greater importance was the rapid growth of `midget' sets, which dominated total U.S. unit sales by the end of the decade. These were sufficiently light to be carried to sports and other outdoor events and thus had a higher relative summer demand than traditional domestic radios. The development of cheap lightweight portable gramophones had markedly reduced seasonality in gramophone sales on both sides of the Atlantic, though in Britain a similarly portable radio was not to become available until after the Second World War.^{xlii}

The role of patent monopolies

The fundamental patents for a valve receiver were developed for radio's initial maritime, military, and long-distance communication uses. Following the First World War, Marconi - which had dominated early radio research - rapidly moved to acquire the main British patents in the entertainment rights to radio, via agreements with British Thomson-Houston (BTH) and significant overseas patent holders. Radio Corporation of America (RCA) developed a similar monopoly over U.S. radio patents, while international agreements (also including France and Germany) gave the dominant firm in each country exclusive rights to use the other companies' patents in their respective territories, together with mutual arrangements wherever possible elsewhere.^{xliii}

In Britain radio broadcasting was regulated by the Post Office, which eventually agreed, in December 1922, to allow six leading electrical manufacturers (the `Big Six': Marconi, BTH, GEC, Metropolitan-Vickers, Western Electric, and Radio Communications Co.) to form the British Broadcasting Co (BBC), with a monopoly over UK-based broadcasting. Listeners were required to pay annual licenses and to use approved BBC sets (which had to be British-made).^{xliv} Until July 1924 the BBC also levied a tariff on receiver

sales, averaging 15 shillings per set. More importantly, from the set-makers' perspective, were royalty payments to Marconi.

The problem facing national radio patent pools in maximising their monopoly rents constitutes a special case of a situation analysed in the vertical integration literature, where a monopolist supplying an intermediate product faces a potentially competitive market of assemblers that can use its output in variable proportions with competitively-priced inputs.^{xlv} While the monopolist could stipulate, as a condition of sale, that fixed proportions must be used in assembly, this would be difficult to enforce - as the monopolist will have imperfect information regarding assemblers' practices. Incentives for substitution by assemblers are predicted to lead to inefficient factor proportions, a problem solved through integrating production (though the effect on final price is ambiguous).^{xlvi}

Marconi tried to block substitution by using a general license, payable if a manufacturer used any of its 13 patents and based on the number of valves per receiver (though levied on the number of valve-holders, as sets were often sold separately from valves). All complying British manufacturers were granted licenses, at a royalty of 12s 6d per valve-holder, while members of the Big Six were charged lower royalties and discounts were later introduced for manufacturers with payments in excess of £5,000 per annum.^{xlvii} Conversely, RCA initially rejected licensing in favour of integration - aiming to control the marketing of all domestic radios, 60 percent of which were to be produced by General Electric (GE) and 40 percent by Westinghouse. This arrangement both solved the variable proportions problem and reflected the circumstances behind RCA's formation - pressure from the American government to end Marconi's monopoly over American radio communications, and GE's aim to create a national wireless monopoly with control over Marconi and Westinghouse patents.

Despite its monopoly exploitation advantages, the RCA – Westinghouse – GE arrangement was undermined by coordination problems. Failing to anticipate the massive growth in demand for household radios during the early 1920s, RCA produced insufficient sets. Meanwhile, the process of getting agreement on specifications between RCA’s sales department and the two manufacturers proved sufficiently slow that some small firms which had obtained “amateur set” licenses from Edwin Armstrong before he sold his patents to Westinghouse were able to both undercut their price structure and beat them to the market with technical improvements. RCA found itself struggling to market obsolescing stock during a period when rapid technical change required good logistics. By 1924 there were some 300 U.S. radio manufacturers, though once the industry moved from crystal to valve sets, RCA’s patent position strengthened considerably and it eventually succeeded in reducing the number of competitors.^{xlviii}

The problems of the RCA-Westinghouse-GE combine were paralleled by those of the Big Six. Despite their lower royalty payments than ordinary licensees, these ‘heavy electrical’ firms, which – apart from GEC – had no background in the consumer goods market, proved too cumbersome to keep up with the rapid pace of an industry characterised by rapid technical progress, frequent design changes, and labour-intensive techniques which limited the cost advantages of quantity production.^{xlix} Marconi’s radio subsidiary, Marconiphone Co., experienced heavy losses, as failures to match production to demand led to accumulations of obsolescent stock, exacerbated by component orders far in excess of reasonable requirements.^l In 1928 Marconiphone was sold to the Gramophone Co., together with half Marconi’s rights to the patent pool (which continued to be administered by Marconi), ending Marconi’s direct interest in receiver production.^{li} The other members of the Big Six fared little better – often incurring serious losses in radio manufacture - and by 1930 all of them except GEC had ceased producing household receivers.^{lii}

Challenges to the patent monopolies

The monopoly power of the patent holders was challenged in both Britain and the United States during the late 1920s, as the radio market grew, non-royalty manufacturing costs fell, and aggressive new manufacturers emerged. Faced with these challenges, the relative success of Marconi and RCA in retaining their monopoly rents was crucially influenced by their national socio-legal environments. British liberal-conservative political economy developed to service what was primarily a financial and mercantile economic elite, emphasising property rights and avoiding state ‘interference’ in private property.^{liii} Meanwhile, following the logic of the liberal-conservative position, British common law had largely abandoned its traditional stance against ‘restraints of trade’ and any judicial actions which reflected this approach were generally reversed by the higher courts.^{liv}

Radio manufacturers considered the 12s 6d royalty excessive, encouraging home construction of radios using kits, or small-scale manufacture by firms that ignored royalty payments – as it was not practicable to enforce patents for large numbers of individuals and micro-enterprises. They also argued that British royalties were unreasonable given maximum German royalty charges of 2s 6d per valve-holder and zero charges in some European countries.^{lv} As the decade progressed other component costs fell markedly, while Marconi refused to reduce its royalty. As Table 4 shows, standard royalties payable on a three valve non-mains set rose from 7.5 percent of the average retail price in 1924 to 8.2 percent in 1926 and 11.0 percent in 1928. As the prices shown are inclusive of essentials such as valves, batteries, and speakers – which were typically sold separately at this time – and retail prices were approximately double factory gate values, the impact on manufacturers’ costs was well in excess of 20 percent by 1928 (except for the expensive newly-introduced mains sets).

[Table 4 near here]

Marconi rejected RMA pressure for a reduced royalty, based on a percentage of the net selling price, rather than a per valve-holder basis. The RMA responded by launching a test-case, when, in 1928 the Brownie Co. approached the Comptroller-General of Patents for a compulsory license covering only two of Marconi's 13 patents. As the set Brownie wished to produce had only two valves and retailed at 25s, the standard royalty would have doubled the selling price, thus allegedly constituting an infringement of the Patents and Design Act, 1919. In August 1928 the Comptroller-General granted the application, while also granting a compulsory license to Loewe, who were setting up a British factory and argued that they should pay the same royalty scale as was paid to Telefunken in Germany – amounting to 10 per cent of the total manufactured cost. Marconi appealed these decisions and in June 1929 at the High Court of Justice (Chancery Division), Mr Justice Luxmoore found in their favour, arguing that Marconi was, 'entitled to monopoly rights flowing from the ownership of patents it had acquired.'^{lvi}

While British business law prioritised private property rights, American legislation had been strongly influenced by fears regarding potential abuses of monopoly power. The Sherman Anti-trust Act of 1890 prohibited individual or collective actions aimed at creating monopoly positions, while the Federal Trade Commission Act and the Clayton Act subsequently empowered the Trade Commission to investigate restrictive practices which might violate the Sherman Act and to enforce prohibitions against anti-competitive practices. American competition policy was significantly weakened during the 1930s, particularly following the the National Industry Recovery Act of 1933, but remained much stronger than in Britain.^{lvii}

As the radio market boomed in the 1920s and competitors encroached on what RCA believed to be its intellectual property rights, it found that enforcing them was more problematic than envisaged. Legal judgements did not always support RCA's position and even when it won, this was often at the expense of adverse publicity, damaged relations with the industry, and increased risk of anti-trust action.^{lviii} Thus RCA reluctantly began offering licenses, initially set at 7.5 per cent of the net selling price. Restrictions, such as a refusal to license the new superheterodyne circuit, and a minimum \$100,000 annual payment, were soon undermined. Smaller companies lobbied politicians to intervene and in 1929 RCA agreed to license all reputable manufacturers. Meanwhile competitors pressed for reductions in the 7.5 per cent fee and in 1932 the royalty was reduced to 5 per cent of the net selling price (and 2.5 per cent for exported receivers), while RCA provided a license bureau to assist with technical performance.^{lix}

Competition in the radio market was based on a combination of performance, design, innovation ('gadgets'), and price. In Britain, the first three factors assumed greater importance relative to the fourth than in the USA, owing to Marconi's flat-rate per valve-holder royalty system, which reduced the proportionate impact of cost-reducing innovations on retail prices. One important exception was innovation in the valve industry which, in contrast to the set market, was dominated by a hand-full of firms, operating as a tight cartel - the British Radio Valve Manufacturers Association (BVA). This set list prices for valves, discount structures, and a common distribution policy, while attempting to block sales of imported valves, or those of non-members. Collective agreements between the BVA and radio manufacturers, distributors, and retailers, cemented its market power, carrying exclusivity clauses prohibiting the agreement holder from handling non-BVA valves.^{lx} Like Marconi, the BVA justified its monopoly position to the wider trade in terms of protecting the

home market from foreign imports, while its behaviour was perfectly legal under British law.^{lxi}

As noted above, the vertical integration literature shows that a competitive assembly industry has strong incentives to substitute against a monopoly input used in variable proportions with competitively-supplied inputs. Royalties based on the number of valve-holders per radio could be reduced by developing multi-purpose valves. Valve-manufacturers found meeting this demand attractive. It provided an avenue for non-price competition –which was not prohibited by the BVA. Furthermore, more complex valves increased brand differentiation, making British valves less interchangeable than their American counterparts and thus further enhancing the local monopoly positions of individual valve manufacturers.^{lxii} Multi-stage valves were also more difficult to make, thus reducing the potential threat from new entrants.

This initiated a path-dependent process of technical change, culminating in fundamental differences in radio design technique between the U.K. and U.S.A.^{lxiii} American ‘tubes’ had low ‘gain per stage’ (of amplification), higher performance being achieved by increasing the number of tubes. Meanwhile they were simple to manufacture, owing to their wide tolerances and limits, and were produced in a narrow range of types in very great quantities, consequently lowering costs. In Britain, by contrast, minimising royalties led firms to employ valves with progressively higher gain, or multiple valves contained in one envelope. These were produced to close tolerances, at substantially higher costs, while manufacturers were able to charge considerable mark-ups owing to their strong cartel position and product differentiation.^{lxiv} While this raised British radio component costs, set manufacturers were prepared to pay a premium for multi-use valves if this was more than offset by lower royalties. The ‘lock-in’ imposed by these conditions proved relatively weak; the mid-1930s saw the start of a gradual process of convergence in valve design, following

the expiration of the industry's fundamental patents and the advent of price-competition in the market for supplying set-makers. Yet - as BBC chairman Sir John Reith noted (in evidence to the Ullswater Committee) high valve costs continued to make British receivers relatively expensive.^{lxv} This is corroborated by data on valve export prices; the USA exported some 7,000,000 valves per annum over 1935-7 at an average price of 1s 8d each, while Britain exported around 1,500,000 in 1937, averaging 5s 4d each.^{lxvi}

Changes during the 1930s

The 1930s witnessed a progressive reduction in the monopoly rents of both the Marconi pool and the BVA, as the sector's fundamental patents expired. From October 1929 it became possible to produce battery or D.C. sets in Britain without any patent infringement, while the expiry of the eliminator patent in December 1931 also made this possible for A.C. sets.^{lxvii} Marconi reacted by re-opening negotiations with the RMA following its victory in the Brownie case. A new 'A3' general license was agreed, with royalties reduced from 12s 6d to 5s per valve-holder, though licensees were required to sign an agreement running for five years from 28th August 1929 and to pay royalties on all their sets, regardless of whether they were covered by the patents. In June 1933 it further reduced its basic royalty, to 2s 6d per valve-holder, under the A4 licence.^{lxviii}

In the United States, RCA's failure to restrict competition led to the emergence of new, aggressive, specialist set-makers, dominated by salesman entrepreneurs, such as Larry Gubb of Philco, Gene McDonald of Zenith, and Benjamin Abrams of Emerson. These pursued strategies of drastically lowering costs and prices, to broaden the market, and developed innovative marketing and production systems.^{lxix} A group of rapidly growing, sales-orientated, specialist set-makers emerged in Britain at around the same time, such as

Ekco, Murphy, and Pye. However, while these shared their American counterparts' focus on marketing, design, and product quality, they were unable to follow their radical price reduction strategies, as these were effectively blocked by the valve-makers.

British valve prices declined more slowly than those of other components and thus formed an increasing proportion of manufacturers' costs.^{lxx} Major valve producers continued to pursue strategies of offsetting high valve prices by reduced patent liabilities. From around 1933 the two leading valve suppliers to U.K. set-makers, Philips-Mullard and BTH, created their own patent pools – with contracts that offered royalty licenses to set-makers and indemnities against patent litigation, but required the manufacturer to tie some or all of their valve purchases to them.^{lxxi} From the middle of 1934, although valves sold to the public remained strictly price-controlled, price-fixing was discontinued for sales to set-makers.^{lxxii} Price competition gradually undermined the complex, high cost, technical path of the British valve industry; for example Philips-Mullard responded by introducing a more limited range of simpler valves.^{lxxiii} Meanwhile the growing market power of the largest independent set-makers enabled them to negotiate prices which progressively reduced valve-makers' margins.^{lxxiv} Despite this, British valves remained markedly more complex and expensive than American tubes.

Higher costs and valve-makers' opposition inhibited Britain from introducing the key US radio marketing innovation of the 1930s, small sets - priced sufficiently low to create a market beyond the household's prime receiver. In 1940 *Radio Retailing* identified four key phases in US radio manufacturing: the home construction era of 1920-23, the rise of the factory-made radio from 1924-29, and the 'replacement and extra set era' of the 1930s - characterised by sharply-falling radio prices.^{lxxv} In 1929 a table top radio cost \$50-75, plus external speaker and valves, while console models cost at least \$100.^{lxxvi} A new, smaller,

cheaper, radio format - the 'midget' - first appeared in California in 1929 and rapidly proved popular.^{lxxvi} In 1932 Emerson pioneered a further size reduction, via the 'compact', modelled on a clock case, 10 inches wide, 6.5 inches high, and four inches deep. Emerson sold over 200,000 of these 'Model 25s', priced at \$25.00 and weighing only six pounds, from their launch late in 1932 to 1933.^{lxxvii}

By 1938 American production of small sets reached an inter-war peak of 4,200,000, out of a national output of 7,000,000 receivers.^{lxxviii} Sound quality improved substantially and they began to take on a much more modern appearance than typical American table top and consol sets, often using coloured Bakelite cabinets. While performance improved, price fell; by 1936 a radio receiver could be purchased complete at a list price under ten dollars.^{lxxix} Their low cost made them suitable as gifts and for use in bedrooms, kitchens, offices, etc., creating a trend for multiple sets per household.^{lxxx} In the early 1940s US replacement demand amounted to only around 9 – 10 million of the 14 million receivers sold, in a market long regarded as saturated in terms of first-time buyers. Furthermore, despite widespread fears that a ten dollar set would damage sales of higher-priced models, in the event the industry experienced significant growth during the late 1930s, as midgets did not seriously challenge the market for the household's prime set.^{lxxxii}

The advent of the midget caused the British radio trade much anxiety. For example in June 1932 Mullard's General Manager, S.S. Eriks, argued that: 'nothing will fritter away our profits quicker than having to keep pace with the Americans, also having regard to novelties they are introducing from time to time, as recently in Chicago.'^{lxxxiii} Yet imports of what Eriks had initially regarded as novelties were reaching Britain in significant numbers by the mid-1930s. In January 1934 *Wireless Trader* noted that these could be imported, duty-paid, at £3 8s per set and by June 1935 a 3-valve midget was being nationally advertised at £3 5s by a major London store.^{lxxxiiii} The main barrier to their diffusion was the trade ban on American-

type valves – as without a supply of replacement valves, sets could not be kept working for any length of time.^{lxxxiv} Legal action by the Marconi pool against importers, distributors, and retailers of American sets also had some impact, though importers circumvented this by dissolving companies threatened with litigation and commencing imports of a different model via a new company.^{lxxxv}

From around 1936 attempts were made to produce lower-priced British sets, but within the constraints of the conventional table top design, rather than the more radical American compact. In evidence to the Ullswater Committee, Reith noted Germany's success in producing a standardised, low-price, 'People's Set'.^{lxxxvi} British developments along these lines were recommended and a number of companies began to market lower-priced receivers. In 1936 Murphy introduced the B23 battery portable, priced at £6 7s 6d.^{lxxxvii} In the same year Philips launched a £6 6s superhet in response to the Committee's recommendations, reducing production costs to £2 10s by mounting the components directly onto the Bakelite case so as not to require chassis.^{lxxxviii}

However, the most enthusiastic response was from the British subsidiary of Philco, which vigorously marketed various 'People's Sets', including the three valve battery B333 for £5 5s and mains versions from £6 6s, launched at the 1936 Radiolympia Exhibition. Although 130,000 Philco 'People's Sets' had been sold by July 1937,^{lxxxix} sales proved insufficient to justify a business plan based on low margins and very high throughput. Philco experienced a 'downfall' early in the trade recession of 1937/8, their attempt to benefit from long production runs resulting in a considerable over-loading of the market and a breakdown of their distribution network.^{xc} At the start of the 1937/38 season Philco had taken the unusual step of raising prices for existing models (by 14.5 per cent for the B333).^{xcii} Meanwhile re-styling was rejected, owing to 'the strict utilitarian nature of the product.'^{xciii} Carrying over an established model at a higher price was anathema to a market based on

annual design changes (or model continuations at discounted prices), and produced a collapse in sales, transforming a 1936 profit of £102,815 into a 1937 loss of £111,504, while a reorganisation which cut staff to one third of 1937 levels failed to improve its position.^{xciii}

The various 'People's sets' were marketed at prices not greatly lower than their cheapest predecessors and were roughly similar in size, weight, and external appearance. As such, they were regarded by consumers mainly as competitors for the main set market, rather than fulfilling the supplementary functions of the much cheaper and more portable American compact. In a market which mainly served replacement demand, most consumers wanted a clearly superior set to their existing model and were thus not drawn to these cheaper models in sufficient numbers; while they had little impact in persuading the British public to adopt the American trend of the multiple set household.

Conclusions

Radio conforms with Broadberry and Crafts' broad argument that the interwar Anglo-American manufacturing productivity gap can be largely attributed to differences in competitive environments. However, two of the three key factors they emphasise, human capital deficiencies and union production restrictions, do not appear to have been significant in this sector.^{xciv} British and U.S. radio manufacturers both employed high levels of female and other un/semi-skilled labour, while contemporary evidence indicates that Britain performed relatively well in those functions where highly-skilled human capital inputs were key – such as technical innovation and design. Meanwhile high female employment severely limited the scope for restrictive union bargaining in what were largely un-unionised sectors. Anti-competitive practices are shown to be important, though – rather than merely keeping inefficient firms in business – these produced complex and path-dependent price, quality, and

technological interactions between an up-stream patent supplier with an initial monopoly position, highly-cartelised intermediate goods (valve) producers; and a relatively competitive final assembly sector.

Patent monopolies are shown to have raised assemblers' costs both directly, and indirectly – by promoting technical developments which were cost-effective given the presence of these rents, but would not have been so in their absence. These factors, in turn, inhibited cost-reducing innovations which might have broadened the market by creating a demand supplemental to the good's initial use – in this case as the household's main receiver. Further research into other dynamic, rapid-growth, manufacturing sectors during this period may provide wider insights into the importance of the cumulative impacts of patent pools and cartels in influencing the costs, technological development, and performance, of 'new' industries in interwar Britain.

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Table 1: A comparison of British and American radio sector labour productivity in 1935.

	UK data for:			US data, converted to £ using:		
	Radio (except valves)	Valves and lamps	Total	Modified Rostas PPP	Exchange rate	General PPP
Gross output (£)	14,879,000	4,660,000	19,539,000	44,960,296	41,014,801	35,665,044
Net output (£)	6,793,000	2,841,000	9,634,000	21,764,312	19,854,382	17,264,680
Employment	32,141	10,595	42,736	44,796	44,796	44,796
Gross output per employee (£)	463	440	457	1004	916	796
Net output per employee (£)	211	268	225	486	443	385
Relative to Total UK = 100						
Gross output per employee	101	96	100	220	200	174
Net output per employee	94	119	100	216	197	171

Sources: UK, Board of Trade, *Final Report on the Fifth Census of Production, Part II*, pp. 330-331; U.S. Bureau of the Census, *Sixteenth Census of the United States*, Volume 2, Part 2, p. 362.

Notes: For modified Rostas PPP, see text. General PPP calculated using purchasing power parity-based deflators derived from Maddison's international GDP data <http://www.ggd.net/maddison/>. See Scott and Walker, "British failure," note 53.

Table 2: U.S. and U.K. radio output and domestic diffusion of radio sets, 1922-37

Year	Production (units)		Households with receivers (USA)		Households with receivers (UK)			Total %
	USA	UK*	No.	%	Licences No.	Unlicensed sets %	%	
1922	100,000		60,000	0.2				
1923	500,000		400,000	1.5	125,000	1.2		
1924	1,500,000		1,250,000	4.6	748,000	6.9		
1925	2,000,000		2,750,000	10.0	1,350,000	12.3	14.6	26.9
1926	1,750,000		4,500,000	16.0	1,960,000	17.7		
1927	2,350,000		6,750,000	23.6	2,270,000	20.3		
1928	3,250,000		8,000,000	27.5	2,483,000	21.9		
1929	4,428,000		10,250,000	34.6	2,730,000	23.9		
1930	3,789,000	600,000	13,750,000	45.8	3,091,000	26.7		
1931	3,594,000	1,258,197	16,700,000	55.2	3,647,000	31.2		
1932	2,446,000	1,436,849	18,450,000	60.6	4,620,000	39.1		
1933	4,157,000	1,281,100	19,250,000	62.5	5,497,000	46.1		
1934	4,479,000	1,756,900	20,400,000	65.2	6,260,000	52.0		
1935	6,030,000	1,849,800	21,456,000	67.3	7,012,000	57.7	14.5	72.2
1936	8,249,000		22,869,000	70.5	7,618,000	62.1		
1937	8,083,000	1,918,000	24,500,000	74.0	8,131,000	65.7		
1938	7,142,000		26,667,000	79.2	8,589,000	68.8		
1939	10,763,000		27,500,000	79.9	8,968,000	71.2	15.3	86.5

Sources: US data, Carter et. al., *Historical Statistics*, Vol. 1, p. 667; Vol. 4, p. 1027. UK production, 1930-32, *Wireless and Gramophone Trader* (28th March 1931), p. 347; (25th March 1933), pp. 318-20; 1930-37, UK, Parliament, *Report on the Import Duties Act*, pp. 128-30; UK, Board of Trade, *Final Report on the Fifth Census of Production, Part II*, pp. 307-11; UK, Board of Trade, *Final Report on the Census of Production for 1948*, p. 7. UK licence and population data, Mitchell, *International Historical Statistics*, pp. 85-87 & 778. Household size calculated using

data from Bowley, *Housing*, p. 269. Unlicensed sets - 1925, Sturmev, *Economic Development of Radio*, p. 155; 1935, Bodleian Library, John Johnson Collection, Wireless Box 10, International Broadcasting Co., "IBC survey of radio advertising penetration, 1935," Sept. 1935; 1939, "The radio market analysed in relation to public purchasing power," *Wireless and Electrical Trader* (19th August 1939), pp. 232-3.

Notes: * 1930-32 data are trade estimates; these include kit radios. 1933-37 estimates are from official sources. These give a higher figure for 1933 than trade data (967,800), which exclude non-members of the RMA . US ownership data are for years to 30th June and UK licence data are for years to 31st March.

Table 3: Annual unit sales of radio sets in the UK (1938) and the USA (1940)

Company	United Kingdom			Company	United States		
	Sets	%	Cum. %		Sets	%	Cum. %
E.M.I.	182,000	14.1	14.1	RCA	1,700,000	14.4	14.4
Philips-Mullard	163,500	12.7	26.7	Philco	1,675,000	14.2	28.5
Cossor	128,000	9.9	36.7	Zenith	1,050,000	8.9	37.4
Murphy	103,500	8.0	44.7	Emerson (mostly midget sets)	1,050,000	8.9	46.3
Bush	93,000	7.2	51.9	Galvin	950,000	8.0	54.3
G.E.C	76,000	5.9	57.8	Colonial (for Sears Roebuck)	650,000	5.5	59.8
Ekco	73,500	5.7	63.4	Belmont	550,000	4.6	64.4
Pye	70,000	5.4	68.9	Noblitt Sparks	400,000	3.4	67.8
Ultra	37,700	2.9	71.8	GE	350,000	3.0	70.8
K.B.	35,200	2.7	74.5	Crosley	350,000	3.0	73.7
Ferguson	32,500	2.5	77.0	Stewart-Warner	250,000	2.1	75.8
Ever Ready-Lissen	30,200	2.3	79.4	Simplex	250,000	2.1	78.0
Graves	30,000	2.3	81.7	Electrical Research Laboratories	250,000	2.1	80.1
Burndept-Vidor	24,700	1.9	83.6	Sonora	200,000	1.7	81.8
Decca	23,000	1.8	85.4	Wells Gardiner (for Montgomery Ward)	200,000	1.7	83.4
McMichael	23,000	1.8	87.2	Detrola	175,000	1.5	84.9
Invicta	21,150	1.6	88.8	Farnsworth	100,000	0.8	85.8
Pilot	18,600	1.4	90.2	Sparks Withington	100,000	0.8	86.6
Others	126,194	9.8	100.0	Others	1,584,000	13.4	100.0
Total	1,291,744	100.0	100.0	Total	11,834,000	100.0	100.0

Sources: Manchester Museum of Science and Industry, Ferranti collection, 1996.10/1/7/409, printed RMA radio output data for year ending 31st Dec. 1938, n.d., c. 1939; Maclaurin, *Invention & Innovation*, p. 146.

Notes: U.S. estimates include exports. Maclaurin believed that RCA had larger exports than Philco, while Philco out-sold RCA in the domestic market.

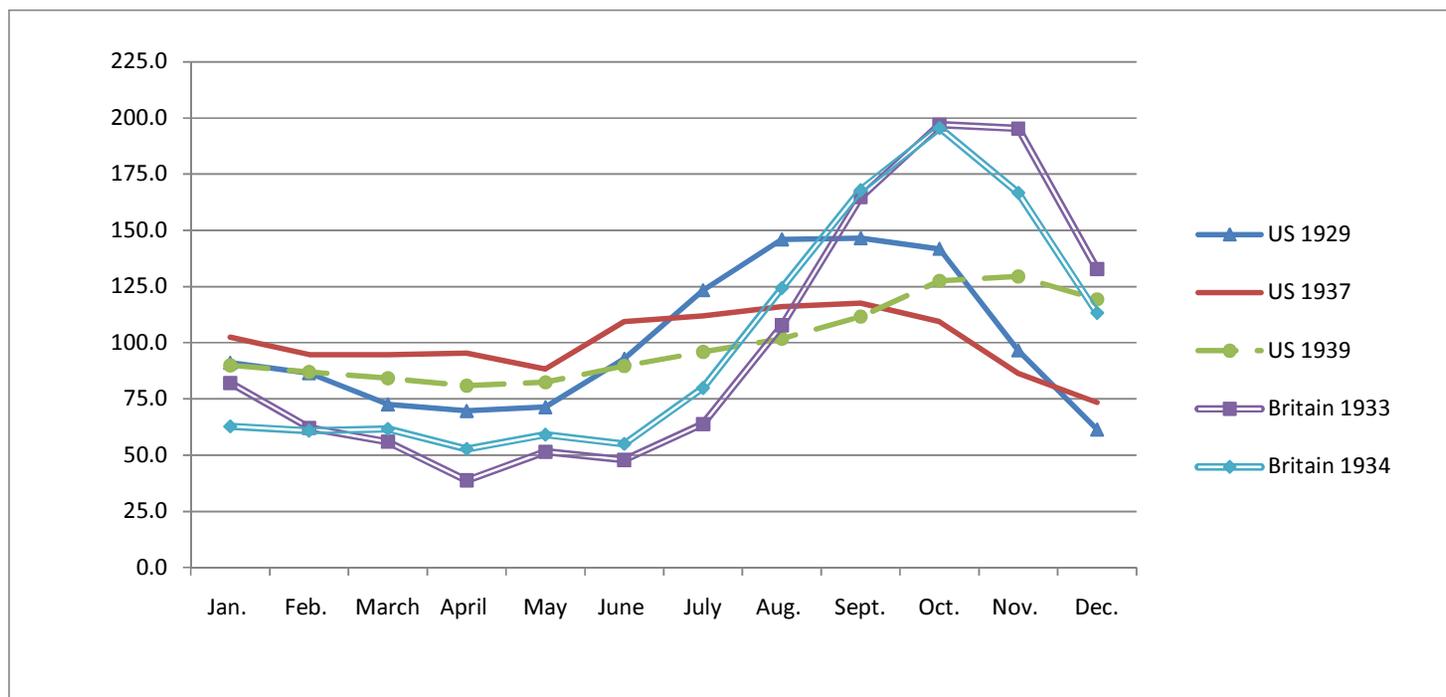
Table 4: Marconi pool royalties as a proportion of the average estimated retail price of wireless sets, 1924-28

No. of valves	1924		1926		1928					
	Price (£)	Royalties (%)								
					Ordinary		Mains		Portables	
1	12	5.2	8	7.8	3	20.8	n.a.	n.a.	5	12.5
2	18	6.9	14	8.9	9	13.9	19	6.6	10	12.5
3	25	7.5	23	8.2	17	11.0	26	7.2	19	9.9
4	29	8.6	38	6.6	26	9.6	33	7.6	25	10.0
5	n.a.	na.	n.a.	n.a.	29	10.8	50	6.3	25	12.5

Source: adapted from Bussey, *Wireless*, pp. 59-73.

Notes: Figures in bold show the sizes with the largest numbers of models produced. Estimates include costs of all essentials, such as valves, batteries, speakers, etc. Radios with over 5 valves are excluded. Royalties are based on the standard (12s 6d per valve-holder) Marconi royalty.

Figure 1: Seasonal variations in radio industry production in the United States and Great Britain (monthly average for each year = 100)



Sources: USA: 1927-29, Manning, “Fluctuations of employment”, pp. 4-8; 1937 and 1939, US Dept. of Commerce, Bureau of the Census, *Sixteenth Census of the United States*, Volume 2, Part 2, p. 391. UK: PCA, 882, England – Mullard Ltd (correspondenteloupant), Vol. 3, Mullard Statistical Dept.statement, n.d., c. February 1935.

Notes: U.S. data are for employment; the 1929 series is based on 17 plants. U.K. data are for all BVA valve sales (for receivers and for replacement purposes).

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ⁱⁱ Rostas, *Comparative Productivity*, pp. 1789-82.

ⁱⁱⁱ See, for example, Maxcy and Silberston, *Motor Industry*; Jones and Prais, "Plant size"; Lewchuk, *American Technology*.

^{iv} Sturmey, *Economic Development*; Maclauren, *Invention & Innovation*. There have been some excellent later studies aimed at more general audiences, for example Geddes and Bussey, *Setmakers*.

^v Broadberry and Crafts, "Britain's productivity gap," pp. 542-3; Broadberry, *Productivity Race*, pp.28-30 & 236. De Jong and Woltjer, "Depression dynamics," Table 5, have recently re-assessed Rostas' calculations, though their figure for 'radios' is based on all electrical engineering

^{vi} Philips Company Archives, Eindhoven [hereafter PCA], 811.2 + S14.2, gegevens radio (Engeland), U.S. Dept. of Commerce, 'Radio Markets – United Kingdom,' 30th January 1934, p. 5.

^{vii} Rostas, *Comparative Productivity*, pp. 179-80.

^{viii} The ratio of operatives to all employees was estimated by Rostas (*Comparative Productivity*, pp. 179-80) at 85 per cent for Britain and 84 per cent for the US. Conversely, data from Board of Trade, *Final Report on the Census of Production for 1948*, p. 30, put the 1935 British ratio at 82 per cent for 'radio apparatus, telecommunications equipment, gramophones, and electric lamps'.

^{ix} Rostas, *Comparative Productivity*, p. 178.

^x Rostas, *Comparative Productivity*, p. 181.

^{xi} Maclauren, *Invention & Innovation*, p. 139

^{xii} Rostas, *Comparative Productivity*, p. 181.

^{xiii} Rostas' (*Comparative Productivity*, pp. 179-80) assumed that 1935 UK labour productivity on non-radio work was around 90 per cent of that for wireless equipment. U.S. productivity for 'phonographs, records, and

other phonographic products' was estimated at around 93 per cent of the level for all radio and associated trades firms. Non-radio production constituted a larger proportion of the U.S. total, though this was partially offset by the addition of radio parts produced by firms in the communications equipment industry, with an estimated labour productivity equivalent to around 87 per cent of that for in-sector wireless equipment production.

^{xiv} Rostas *Comparative Productivity*, p. 33; Broadberry and Crafts, "Britain's Productivity Gap," p. 542.

^{xv} See, for example, Ward and Devereux, 'Measuring British decline'.

^{xvi} Sturmey, *Economic Development of Radio*, p. 155.

^{xvii} Bodleian Library, Oxford, John Johnson Collection, Wireless Box 10, International Broadcasting Co., 'IBC survey of radio advertising penetration, 1935', unpublished report, Sept. 1935; 'The radio market analysed in relation to public purchasing power', *Wireless and Electrical Trader* (19th August 1939), pp. 232-3. The 1935 study is probably the most reliable - based on a survey of 9,029 households from 13 towns in England, Scotland, and Wales, weighted for geographical area and socio-economic class.

^{xviii} Source: "Marketing statistics and sales... 1937," *Radio Retailing* (Jan. 1938), 25-32, p. 32.

^{xix} Bowden and Offer, "Household appliances," 725-48.

^{xx} Landes, *Unbound Prometheus*, p. 428.

^{xxi} Bodleian Library, John Johnson Collection, Wireless Box 10, International Broadcasting Co., "IBC survey of radio advertising penetration, 1935," Sept. 1935; "The radio market analysed in relation to public purchasing power," *Wireless and Electrical Trader* (19th August 1939), pp. 232-3.

^{xxii} "Marketing statistics and sales... 1937," *Radio Retailing* (Jan. 1938), 25-32, pp. 26-7; U.K. Customs and Excise, *Annual Statement of Trade*, pp. 160-61.

^{xxiii} "Marketing statistics and sales... 1937" , *Radio Retailing* (Jan. 1938), 25-32, pp. 26-27.

^{xxiv} UK, Board of Trade, *Final Report on the Fifth Census of Production, Part II*, p. 330; Final Summary Tables, p. 3.

^{xxv} U.S. Department of Commerce, Bureau of the Census, *Sixteenth Census. Volume I*, p. 19; Vol. 2, pp. 362 & 388.

^{xxvi} Rostas, *Comparative Productivity*, p. 182.

^{xxvii} UK, Board of Trade, *Final Report on the Fifth Census of Production, Part II*, p. 330.

^{xxviii} Source: US Department of Commerce, Bureau of the Census, *Sixteenth Census. Volume 1*, pp. 190 & 214.

^{xxix} This was a recessionary year for the British radio industry. For example, Pye's production for 1937 was given as around 200,000 sets, compared to the 70,000 shown for 1938. Geddes and Bussey, *Setmakers*, p. 132.

^{xxx} In 1933 the largest nine radio set manufacturers accounted for an estimated 74 per cent of the industry's turnover, compared to 70.8 per cent in 1940, Langley, "Radio developments," p. 433.

^{xxxi} "Autolyucus", "The all-electric advertising Man: Richard Haigh, English Manager of the Gramophone Company, talks to us about radio (and records)," *Advertising World*, 65, No. 4 (April 1934), 181-2, p. 182.

^{xxxii} Manchester Museum of Science and Industry, Ferranti, 1996.10/10/1/1, V.Z. de Ferranti to A.E. Cutforth., 12th January 1932.

^{xxxiii} Manning, "Fluctuations of employment," p. 32.

^{xxxiv} Wilson, *Ferranti*, p. 256; Lipman, *Memoirs*, pp. 65-66.

^{xxxv} Geddes and Bussey, *Setmakers*, p. 204.

^{xxxvi} Cones and Bryant, *Zenith Radio*, p. 50; Ramirez, *Philco Radio*, p. 53.

^{xxxvii} Saunders, *Seasonal Variations*, pp. 262-3.

^{xxxviii} "Some current advertising," *Advertising World*, 65, 7 (July 1934), p. 390.

^{xxxix} Eoyang, "Economic study," pp. 93-4.

^{xl} U.S. Department of Commerce, Bureau of the Census, *Sixteenth Census, Volume 1*, p. 82 (covers wage-earners, managers, and clerks in manufacturing); UK, Board of Trade, *Final Report on the Census of Production for 1948*, p. 3 (covers operatives, plus managerial, technical, and clerical employees).

^{xli} Sources: U.K. - The National Archives, Kew [hereafter TNA], BT96/224, un-dated data sheet of U.K. radio output (units) for 1939; U.S. - '1938 radio business at a glance,' *Radio Retailing* (Jan. 1939), pp. 12-13.

^{xlii} Nott, *Music*, pp. 40-41.

^{xliii} Maclauren, *Invention & Innovation*, p. 107.

^{xliv} Radcliffe Science Library, Oxford, Marconi collection [hereafter RSL, Marconi], Ms 323, Marconi co., "The development of broadcasting in Great Britain. A general review of the lines along which broadcasting has developed," n.d. c. 1923-4.

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- ^{xlv} Vernon and Gordon, "Profitability of monopoly," 924-25; Schmalensee, "Note on the theory of vertical integration,; Warren-Boulton, "Vertical control".
- ^{xlvi} Williamson, *Markets and Hierarchies*, p. 85; Warren-Boulton, "Vertical control".
- ^{xlvii} Sturmev, *Economic Development*, pp. 215-19.
- ^{xlviii} Maclauren, *Invention & Innovation*, pp. 107-18.
- ^{xlix} Geddes and Bussey, *Setmakers*, p. 29.
- ¹ RSL, Marconi 588, Report on investigation of Marconi Wireless Telegraph Co. by Price Waterhouse & Co. and Cooper Brothers, 20th January 1927, folio section, pp. 60-61.
- ^{li} Sturmev, *Economic Development of Radio*, p. 166.
- ^{lii} RSL, Marconi, 3024. `Memorandum for information of directors of the board of Associated Electrical Industries Ltd, July 1929.; Sturmev, *Economic Development of Radio*, pp. 148 & 167.
- ^{liii} Harris, *Competition*, p. 25.
- ^{liv} Hannah, *Rise of the Corporate Economy*, pp. 42-3.
- ^{lv} Sturmev, *Economic Development*, p. 217.
- ^{lvi} *The Times*, 19th June 1929, page 5.
- ^{lvii} Broadberry and Crafts, "Britain's productivity gap," p. 547.
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