ISSN 1755-5361

University of Essex

Department of Economics

Discussion Paper Series

No. 701 November 2011

Shorting the Future: Capital Markets and the Launch of the British Electrical Industry, 1880-1892

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November 9, 2011

Abstract

Drawing on a comprehensive data set consisting of dividend payments, security prices, and stock exchange disclosures, this paper argues that, contrary to common interpretation, potentially damaging government regulations imposed in 1882 cannot explain the retarded development of the nascent British electrical industry in its first decade. Instead, as informed opinion at the time maintained, wildly inflated expectations had by the spring of 1882 driven the publicly-traded security prices of putative electrical enterprises to manifestly unsustainable levels. When initial demand and operating profits failed to meet these grossly extravagant expectations, "irrational exuberance" quickly turned to equally undisciplined pessimism in a classic case of stock market boom and bust - with predictable consequences, most notably a collapse of subsequent investment and development at a time of great technological ferment, when durable early-mover advantages were being established among electrical manufacturers globally. This debilitating sequence of market boom and bust was further exacerbated by the fact that during the brief boom surprisingly little money was invested in the promising technologies that were available. Technological rather than regulatory risk was the dominant factor in the 1882 electrical debacle, with long lasting consequences.

Keywords: Origins of British Science-based Industries, Finance of British Innovation, Stock Market Crashes, British Electrical Industry.

JEL classification: N23, N28, O33, L94.

We gratefully acknowledge financial support from the LSE's Staff "Pump-priming" Scheme and the Leverhulme Trust and computing support from NUI Galway. Roy Bailey, Leslie Hannah, and Eddie Hunt made detailed and perceptive comments on earlier versions of this paper. Any remaining errors are ours.

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'The forces of the nineteenth century have run their course and are exhausted. [W]e must find a new way and must suffer again the malaise, and finally the pangs, of a new industrial birth.'

The Economic Consequences the Peace
J.M. Keynes

I.

There are three reasons why the electrical industry's origins command attention.[1] First, the industry in all advanced countries grew much faster than its host economy, starting from virtually nothing in the late 1870s and reaching substantial size in the more industrialized ones by 1913 – accounting for perhaps 10% of Britain's annual gross domestic capital formation by 1900 and at least that much in the U.S.[2] During the late nineteenth century the industry spawned a myriad of firms, including huge ones, such as General Electric in the U.S. and Siemens in Germany, which still remain among the largest in the world, as well as employing hundreds of thousands of workers.[3] By 1914, the industry's size and rate of growth had a material impact on national macroeconomic performance. Secondly, the bulk of the industry's rapid growth from the mid-1880s onwards was driven by emerging productivity-enhancing applications in industry and transportation rather than the lighting uses first envisaged, although demands for the "light of luxury" continued to grow quickly and remained significant. The speed and skill with which electrification was pursued thus came to have a large and growing impact on productivity, especially labour productivity. [4] Finally, progress in electrification quickly came to depend on an understanding of underlying scientific principals and electrical companies soon joined their chemical-industry counterparts in forging close links with academic scientists and engineers. Such links came to have an enduring impact on much high-level human capital formation. The expansion of the electrical industry created a persistent demand, felt most keenly where growth was rapid, both for men with advanced scientific research capability and for men with more immediately practical engineering skills, the successful application of which demanded an unusually high level of mathematical sophistication.[5]

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[1] In this paper, the electrical industry includes all electrical activity except telecommunications.

[2] Byatt, *Electrical Industry*, p.5.

[3] GE is the only one of the original constituents of the Dow Jones Industrial Average still in the index in a recognizable form.

[4] David, "Dynamo and Computer"; Mowery and Rosenberg, *Paths*; David and Wright, "General Purpose Technologies"; Gordon, "New Economy".

[5] Klein, *Steinmetz,* pp.7, 19-22. For example, Edison's English consulting engineer, John Hopkinson, had graduated from Cambridge as senior wrangler in the mathematical tripos. Klein (*Steinmetz*, pp.7, 27, 37-38) also describes the impact of the demand for electrical engineers upon the curriculum of American engineering schools, especially in terms of increased mathematical requirements.

As is well known, electrification in Britain proceeded remarkably slowly and hesitantly.[6] By 1890 Britain was clearly lagging the U.S. and Germany in the development of the new technology in terms (adjusted for population size) of the number of installed electric lamps; the number and efficiency of central generating stations; the extent of non-lighting applications of electricity; the size and profitability of electrical companies; the extent of electrical exports; the miles of electrified rail and tram tracks; and, above all, the intensity of experimentation and innovation. Moreover, the lag that had emerged by 1890 continued to widen rather than narrow.[7] This performance was as surprising as it was disappointing. When the industry first emerged in the late 1870s, Britain was easily the wealthiest country in Europe and home of the world's largest, deepest, and most sophisticated capital markets. Not surprisingly, innovation in the birthplace of the Industrial Revolution was strong: in December 1878, Joseph Swan demonstrated in his native Newcastle a functioning prototype of an incandescent lamp virtually simultaneously with Thomas Edison. Wealthy British consumers – notably Lord Salisbury, a future Prime Minister, and Sir William Armstrong, a prominent industrialist - were among the first in the world to have their private residences lit by electricity (using Swan lamps). The British scientific base was also strong: the Cambridge-based Scotsman, James Clerk Maxwell, had in the 1860s provided a powerful theoretical basis for understanding the related phenomena of electricity and magnetism. The Cambridge-educated polymath William Thomson (later Lord Kelvin) built on Maxwell's work to further advance scientific understanding of electrical phenomenon at the highest level. Highly competent British engineers such as John Hopkinson and Charles Merz were soon eagerly sought as consultants by electrical firms world-wide. With venturesome consumers, receptive capital markets, inventive entrepreneurs, and skilled scientists and engineers, wealthy Britain was thus poised to be amongst the leaders of electrification. But it didn't happen.

Given the significance of the electrical industry, historians have sought to understand this perplexing performance. Although a variety of explanations have been advanced - ranging from innate conservatism to unusually fierce and effective competition from Britain's long-established gas industry to the crippling effects of an early stock market crash - the explanation currently proving most persuasive among historians is that inept government intervention and regulation hobbled the industry from birth.[8] A.A. Bright, whose views are representative of a long-held belief, expressed the argument succinctly:

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[6] See, for example, Bright *Electric-Lamp*, pp.106-9; Broadberry, *Productivity Race*, pp.241-44; Byatt *Electrical Industry*, pp.1-10, 210-19; Hannah, *Electricity*, pp.8-9, 37-8; Clapham, *Economic History*, p.109; Hughes *Networks*, pp.60-66; 227-261; Kennedy, *Industrial Structure*, pp.29-31;and Michie "Finance", pp.506-518. By early 1888, only six companies and a smattering of municipalities were offering a public electricity supply in Britain whereas Edison had by then established 149 public central stations, with Westinghouse, Thomson-Houston, and others scrambling to catch up with scores of stations (Wilson, *Ferranti*, p.31).

[7] See especially Hughes, *Networks*, pp.238-247, 257

[8] See, for example, Bright *Electric-Lamp*, pp.106-9; Hughes, *Networks*, p.64; and Michie "Finance", pp.506-09, 518, Parsons, *Early Days*, pp.189-98, among many others going back to the 1880s, although few consider the evidence in detail. For evidence of the persuasiveness of the regulatory hypothesis see Crafts' influential survey of Victorian economic performance ("Long-run", especially p.17). Regarding gas, it must suffice here to note that Thomas Edison believed not only that competition from gas posed no insurmountable threat to his electrical

> The Electric-Lighting Act [of 1882; hereafter "The Act"] had effects not foreseen by Parliament. Instead of provoking caution in central-station electric lighting, it stifled commercial development. [9]

This Act, under deliberation since 1879, was finally passed on 18 August 1882. Its motivating rationale was to avoid the abuses gas and water companies had long practiced, exploiting the grant of irrevocable local monopolies to charge exorbitant prices for poor service. The Act broke new ground to give, through Provisional Orders (PO) subject to parliamentary approval, powers to the Board of Trade (BoT) to grant private companies exclusive concessions to supply electricity in defined areas, without the consent of local authorities. While the Act also gave local authorities first refusal in applying for a PO, it sought to ensure that they could not block companies unreasonably (say, to protect municipal gas undertakings). When granted, POs gave companies rights to excavate streets (normally the preserve of municipalities) but also carried an option for local authorities to purchase the business at the market value of fixtures and fittings without allowance for goodwill (or future profit) after a period of time set initially at seven years, but lengthened to fifteen years in Commons debate, and finally to twenty-one years by Lords amendment. This provision (only later called "scrap metal") was not the only aspect of the bill to be controversial. Other contentious matters at the time included the extent of the BoT's powers; its competence (it was considered lacking scientific expertise); the extent to which applicants would be constrained to provide service; and the extent to which ratepayer's money might subsequently be wasted through municipal incompetence. [10]

More recent studies have sustained the belief that the Act's compulsory-purchase provision damaged the nascent British electrical industry.[11] For example, Michie approvingly quotes the contemporary financier R.H. Benson's retrospective assertion that in the summer of 1882 the British government's reforming zeal drove 'too hard a bargain' in favouring municipalities at the expense of private enterprises.[12] Other informed contemporary observers, such as Sir Frederick Bramwell, Lionel Cohen, James Staat Forbes, and Emil Garcke had also, like Benson, later come to blame perverse regulation for the industry's difficulties, although in

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ventures, he actively sought it out. He considered lighting markets without gas competition unattractive, and for companies operating there he demanded full payment in cash on delivery for goods and services. But if gas competition were present, Edison would share the risk of competition by accepting securities in part-payment for equipment (Passer, *Electrical Manufacturers*, p.118). That strategy worked. In the U.S., Britain, and Germany, successful electric utilities first emerged in affluent neighbourhoods where the benefits of reliable electric lighting far outweighed any cost advantage gas might have temporarily offered. It should also be noted that the dominant gas company in the lucrative London lighting market of the 1880s, the Gas Light & Coke Company, was notoriously cautious, technologically weak, and, after a feeble exploration of electrical lighting technology, responded to its advent solely by seeking legal obstacles to thwart it. See Everard, *The History*, pp.254-85.

[9] Bright, *Electric-Lamp*, p.107.

[10] For a contemporary alarmist view of the Act, replete with considerable detail, see Beauchamp Gordon, "A Plea".

[11] Michie, 'Finance'.

[12] Ibid, p.516.

1882 Bramwell had told the Parliamentary committee then deliberating the Electric Lighting bill that 21 years of private operation – then the most contentious aspect - would be adequate.[13] Thus on the basis of contemporary if retrospective criticism, supported by the inference that British investors instinctively sought profitable opportunities unless blocked, Michie concluded that the Act decisively discouraged investment in the industry, thereby stunting its development.[14]

Authoritative observers in the spring of 1882, however, were struck not by regulatory risk in the far future but by the immediate spectacle of conspicuously "noisy" share markets and strong suspicions of manipulation. This view was expressed clearly by *The Economist* newspaper on May 20, 1882 (pp.604-05):

> On the morning of May 16, the £238,000 representing the Anglo-American Brush Company's paid-up capital was apparently worth in the market £1,721,000, yet such is the fickleness of this market that up to yesterday afternoon, that same capital had lost £600,000 of that market value. … The rage for these securities has been enhanced by some considerable 'cornering' operations, and the moment has been seized to flood the market with a host of off-shoots, respecting which only this can be said, that the vendors have shown themselves most ready to transfer their interests.
>
> The electric light is very probably a great invention, and, for the sake of argument, let us take it for granted that its future development will be vast. ... But this, unhappily, cannot be urged as a reason why the pioneer companies should be prosperous...The history of our great company manias has always proved the contrary**. ...**The greatest invention of the century resulted in the railway mania of 1845-46, and few were bold enough then to say it was not justified. ... [Y]et.. never since, prosperous as our railways have been, have such high prices [as in August 1846] been touched.
>
> ... [H]owever great a revolution may possibly be in store for us, the inevitable competition amongst the rival electrical systems will effectively prevent the shareholders from becoming millionaires, though that role may possibly be played by the vendors.

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[13] *The Times*, July 17, 1882. *The Economist* (July 22, 1882, p.907) agreed with Bramwell's original view that the option of compulsory purchase on strict terms after 21 years was appropriate, for if future earnings were to be the basis of municipal purchase, supernormal profits would have to be more tightly constrained somehow (since PO's created monopolies and companies avidly sought them), otherwise the companies would get '…a double gain'. Hughes, *Networks*, pp.60, 63. Robert Hammond, a prominent British electrical entrepreneur, concurred; see Hannah, *Electricity*, p.6, 362. At a 3% discount rate (approximately the Consol rate), the present value of £100 received in 21 year's time is £53.75; at 6% (the best available estimate of the realized rate of return on domestic British equity investments in the late nineteenth century) £29.42.

[14] Michie, 'Finance', pp.507-510.

The same article also observed the technological uncertainty shrouding the nascent industry, quoting directly the glowing – and flatly contradictory – claims found in no less than nine prospectuses circulated by aspiring companies, concluding:

> One thing is certain. All claim to be the best; and where electricians of the highest repute so differ as to results, the general public cannot yet arrive at any sound conclusion.

Conspicuously, *The Economist* did not add prospective regulation to the factors driving the remarkable volatility of electrical industry share prices.[15]

Nor did other seasoned market observers, such as the successful company promoter, H. Osbourne O'Hagan. Like others, O'Hagan was struck by the intensity of market speculation and rumour-mongering**.** Many market professionals were notably sceptical about Anglo-American Brush's prospects, believing 'the [Brush] shares would go down as quickly as they had been put up', and, accordingly, vigorously sold the shares short. [16] To cover their positions, the short sellers actively circulated evidence when they had it and rumours when they didn't that the Brush patents were weak and that already in several places the Brush system had been discarded and replaced by one or another of its numerous rivals.

> The word went round, "See what has happened in Paris". No one knew what had happened in Paris and no one inquired. [17] It all helped to frighten speculators and with a vigorous campaign against the Brush, Hammond, and Metropolitan shares, the bubble burst, the shares tumbled down many points in a week, and the Metropolitan Brush shares which were a few days before selling at £4 per share premium [i.e. £7] could not be sold at par [i.e. £3]. This was one of the worst slumps I have ever witnessed, for the speculating public were just as anxious to get out of their shares as a week or two before they had been anxious to acquire them.[18]

While historians have often noted the electrical bubble of 1882, none have linked it closely to the industry's subsequently faltering development, although several have acknowledged the possibility - Byatt for example observed simply that "the consequences for manufacturing of the first boom of 1882 were particularly unfortunate", but did not develop the

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[15] Presciently, *The Economist's* comments very nearly marked the peak of Brush's market capitalization.

[16] O'Hagan, *Leaves*, p.121. O'Hagan himself may have been prominent among them. He allegedly made £100,000 dealing in the shares of Metropolitan Brush, which he had promoted. It is hard to see how such a sum could have been made without short selling. See Reader, *A House*, p.96.

[17] Edison, not Brush, Swan, or Maxim, all exhibiting there, had won the greatest acclaim for electric lighting. Hughes, *Networks*, pp.50-1.

[18] O'Hagan, *Leaves* pp. 122-23.

thought further.[19] In taking this view, historians have accepted far too uncritically the retrospective assertions made by influential contemporaries - many of them financiers such as Benson and Lionel Cohen, a prominent Stock Exchange official - that perverse legislation had retarded the early development of the British electrical industry.[20] Not only has the evidence for such assertions gone unexamined, but no consideration has been given to the incentives market professionals had in making them: after all, it was far easier for financiers to blame ill-drafted legislation than to acknowledge that the very markets from which they drew their fortunes were occasionally prone to bouts of wealth-destroying madness, which they might have encouraged (and from which they might have benefited). Hence recent interpretations of the origins of the British electrical lag have generally accepted the view that it stemmed from Parliament's apparent decision in 1882 to favour municipal development of the new industry at the expense of private enterprise.[21] However, a closer look at the evidence suggests that those informed contemporaries who stressed a volatile bout of ill-informed speculation followed by irrational pessimism and profound uncertainty in the face of technological and financial setbacks, understood well the causes and anticipated clearly the consequences of the stock market boom. This is not to claim that the controversial regulatory legislation of 1882 was actually helpful – no one has argued that. But in the presence of much more immediately pressing issues – getting equipment to work acceptably and signing up paying customers in the wake of a resounding market crash - the legislation was either irrelevant or of only trivial importance.

Drawing upon data on share prices, dividends, and liquidation payments to plot the course of the electrical boom and bust, we show that the electrical bubble inflated heedless of the alleged adverse consequences of the Electric-Lighting Act or competition from gas and only began to implode as evidence of manifold, unexpected technological shortcomings emerged. Characteristically, in the wake of the crash, investment abruptly ceased to flow into the technologically-demanding industry, despite great need for continued experimentation and development. For more than a decade after the bursting of the electrical bubble, the new cash that flowed into the industry rarely reached 20% of the 1882 level and it would be almost twenty years before the 1882 level was approached again. Moreover, we show that much of the limited money committed to the industry's engineering segment for nearly a decade after 1882 came from calls on shares issued by companies in 1882 or earlier. Yet these companies – with only one partial exception – were remarkably unprofitable by the standards of later British electrical-engineering companies, let alone foreign ones. It was in this 'lost' decade following the 1882 debacle that Britain's electrical lag first emerged, never to be made good.

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[19] See for example, Byatt, *Electrical Industry*, pp.8, 18-19; Bright, *Electric-Lamp*, pp.106-07; Hughes, *Networks*, pp. 57, 61-2. Kynaston, *City of London, Vol. I*, pp.340-44, is a notable exception, but even he accords more blame for the crash to the 1882 Act than it warrants.

[20] Hughes, *Networks*, p.63.

[21] Hughes, *Networks* pp.62-66 (but with qualifications); Michie, "Finance", pp.513-18, 528-30, Crafts, "Long run", pp.11-17.

The paper is organized as follows: Section II describes the data we use to construct Table 1, which identifies the groups raising money in 1882, the amounts raised, and the returns earned. Share prices are used to plot the course of the bubble and its aftermath and their movements examined for response (or not) to the Act's passage through Parliament. The total returns down to 1914 earned by these groups of companies are also calculated. Section III considers possible explanations for the boom and bust and considers how the electrical companies of 1882 came to the Stock Exchange, examining the claims made in widely-circulated prospectuses, the composition of boards of directors, and the extent of purchases of assets from company founders and directors. Section IV considers the consequences of the 1882 bubble. Section V concludes.

II

Unless otherwise noted, our data are drawn from two sources widely used by market participants at the time: the first, *Burdett's Official Intelligence* (after 1898, the title was changed to *The Stock Exchange Official Intelligence),* appeared annually.[22] The second, *The Investor's Monthly Manual (IMM)*, was published by *The Economist* newspaper until June, 1930. *Burdett's* provided authoritative information on a company's capital structure, comprising: (1) the number of various types of equity shares (ordinary, deferred ordinary, preferred, etc.) authorized and issued, together with their nominal (face) values; (2) whether the shares were issued for cash or for non-cash assets, such as patents or property; (3) the amount called up on the shares (most shares issued for cash were initially only partially paid-up, the remainder due being "called up" over time until the full nominal amounts were paid); (4) the volume and nominal value of debenture stock issued; (5) listing details (e.g. whether also listed on provincial exchanges); and (6) a record of any recent dividend and other payments. *Burdett's* also usually provided some brief statement of the company's ostensible business, its officers, the company's address, and other basic information, often including the high and low market prices of ordinary shares during the previous year and rudimentary accounting data, such as the balance on profit and loss account. We obtain our price data from the *IMM,* perhaps the most widely followed contemporary source of such data before 1914. Only a minority of the companies registered with the London Stock Exchange – usually the largest and most important ones - had securities sufficiently actively traded to ensure that their prices appeared regularly in the *IMM*. However, at least some of the securities of almost all successful companies were eventually quoted in the *IMM* (closely-held Siemens Brothers was the great exception). For all companies, whether their securities were quoted in the *IMM* or not, we have a record of the total money they received

[22] *The Stock Exchange Official Intelligence (SEOI)* first appeared in 1882 as *Burdett's Official Intelligence,* published by Henry C. Burdett, then secretary of the Share and Loan Department of the London Stock Exchange, under sanction of the Committee of the Stock Exchange. The title was changed in 1899 to emphasize the official nature of the publication, as Burdett's successors in the Share and Loan Department of the Stock Exchange remained as editors. Thus this publication always constituted a more "official," and therefore, presumably, more reliable, record than its competitors. The principle of these, *The Stock Exchange Year Book*, edited and published by Thomas Skinner from 1874, eventually merged in 1934 with *SEOI* to form the *Stock Exchange Official Year Book* with editorial control passing permanently to the secretary of the Stock Exchange's Share and Loan Department.

from the issue of securities (gross of issue expenses) and the total amounts they paid to holders of them. These data allow some estimate of a company's profitability even in the absence of security prices.

The dimensions of the 1882 stock market boom and subsequent bust are summarized in Table 1. The 38 electrical companies[23] offering varying combinations of 13 different patented technologies and issuing shares in 1882, are organized in the table into eight technological groupings, shown in descending order of the cash raised over the lifetime of the group by means of the issue of ordinary shares (Column 1); the cash raised in 1882 alone is shown in brackets.[24] Column 2a shows the cash and 2b the nominal value of shares the companies paid for patents and other assets. Column 3 shows the total cash payments the companies made to the holders of ordinary shares (including liquidation payments). Column 4 notes the fates of the 38 companies down to end-June 1914: 28 were liquidated and 9 disappeared through merger or takeover.

Table 1 includes virtually all the prominent pioneers of electric lighting, all drawn to Britain by its wealth, its unequalled global commercial connections, and its vast capital markets.[25] All the largest share issuers boasted well-known technologies, the largest being that of Charles Brush. By 1881 his innovative sets had captured some 80% of the rapidly growing arc-lighting market in the U.S., with large and influential demonstration displays in his native Cleveland, Ohio, on New York's Broadway, and elsewhere. The company – Anglo-American Brush (A-AB) – created to exploit his technology outside the Americas also purchased rights to the patented incandescent-lighting system of the English inventor, St. George Lane-Fox, thereby addressing both segments of the emerging electrical-lighting market. A-AB was supported in its impressive sales growth by Robert Hammond, A-AB's star British arc-lighting salesman, who, following great success in 1881, set up his own company to sell, install, and maintain lighting sets, relying heavily on the Brush and Lane-Fox technologies, rights to which he obtained on favourable terms. Similarly, A-AB, in return for generous payments of cash and shares, sanctioned a further 15 companies, eleven British-based and four overseas, to build on A-AB's sales success in selected regional markets. Had all the Brush electricity-supply concessions succeeded in this bold strategy, they would have spanned all Britain, its Empire and much of Europe as well. In conjunction with Charles Brush's own American ventures, they would have dominated the global electrical industry from its birth.

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[23] This number refers only to companies that were both registered with the London Stock Exchange **and** sought to raise money by the issue of securities to the general public. It does **not** include the potentially large (but unknown) number of enterprises that raised money on a much more restricted, often informal basis, from the time-honoured sources of acquaintances and family. However, no subsequently successful electrical company was launched in 1882 employing these traditional means.

[24] The focus is properly on ordinary shares. Only £400 of preference shares were issued in 1882, and no fixed-interest securities, although many companies issued both after 1890.

[25] See Bright's definitive study, *Electric-Lamp*, pp.44-57. The fractious Sawyer-Man partnership was the only (partial) exception.

However, Brush's was not the only famous name to contest the market. Joseph Swan was widely known for his lighting displays in prestigious English residences and the Savoy Theatre. But unlike Brush, he focused on the lucrative, but technologically challenging, incandescent-lighting market. Nor did he attempt simultaneously to float a swarm of supply concessions. Another group bought the British rights to both Maxim-Weston lighting systems already in operation in New York. Maxim-Weston Electric, like A-AB, but on a much smaller scale (2 per cent of Brush's), also established a supply subsidiary, in Lancashire. Another well-known electrical entrepreneur was Paul Jablochkoff, a French-based retired Russian army officer and telegraph engineer, who had built one of the first operationally viable arc-lighting systems. His dazzling displays in the late 1870s in Paris and London did more than anything else to usher in the international craze for electric lighting, inspiring, among others, Charles Brush, Thomas Edison, and Sir William Siemens. Like Brush, whose origins were also in the technologically simpler, easy-to-enter arc-lighting business, Jablochkoff also secured rights to an incandescent lamp (Maxim-Weston's) in order to address both lighting markets. Like Swan, Jablochkoff did not also float supply concessions.

The promising British and Imperial electrical-lighting markets attracted still another American, Thomas Edison. In March 1882, through introductions made by his well-connected patent attorney, who enjoyed close links to the influential Morgan financial partnerships, Edison launched the English Electric Light Company with an eminent board of directors and an authorized capital of £1 million (but with only £20 thousand called up).[26] Despite the company's wealthy and distinguished backers, it kept a low public profile. It never had an entry in *Burdett's,* it never sought to sell shares to the general public, and its shares were never quoted in *The IMM.* Nevertheless Edison's English Electric Light did modestly emulate the Brush and Maxim-Weston strategy of affiliated supply concessions: it sold patent rights to two concessions that were both registered with *Burdett's* and issued shares to the general public - one serving Manchester, the other an Imperial venture targeting India and Australia.

Interest in lighting also extended to peripheral equipment. The Frenchman Camille Faure, a well-known inventor and manufacturer of storage batteries, demand for which was likely to grow with the lighting boom, established his own company. At the same time Faure was a key participant in the formation of Electrical Power Storage Company (EPS), a Stock Exchange-registered company but essentially an unquoted patent pooling vehicle of all the main battery innovators of the time, including Swan, Emil Volckmar, and J.S. Sellon. EPS raised no cash but promised to hold a dominant share of whatever demand for batteries might emerge from the newly-emerging electrical market. Sensing buoyant demand in Asia, Indian & Oriental Electrical Storage & Works Company, was created to market the Faure-EPS technology there.[27] The company worked closely with another, Eastern Electric Light & Power Company, seeking

[26] Hughes, *Networks*, p.54. See also Hausman, *et.al.*, "Global Electrification", pp.179-180.
[27] *Burdett's*, Vol. II.

to supply "electric light and motive power in India and other Eastern countries".[28] In addition to these seven high-profile groups, there were 12 lesser-known ones - individually raising smaller, but cumulatively significant, amounts of money - lumped together as "The Rest" in Table 1. Eleven of these companies were niche producers of electrical equipment - often patented - such as dynamos, incandescent lamps, and arc-lamp carbons. One specialized in electrical installations. Thus these eight groups offered allegedly astute investors a wide, not to say bewildering, variety of opportunities to participate in the new industry.

Table 1 reveals their participation was signally unprofitable. Comparing Column 3 totals (total cash returned for all companies) with Column 1 totals (total cash raised by all companies) and adding £82,000 (the end-June 1914 market value of the securities of surviving companies) reveals the scale of losses.[29] The cash and marketable securities ultimately received by the shareholders of the all the 1882 companies came to only 43.5 per cent of the cash they had together committed to the industry and was only slightly greater than the amount spent on patents alone. And of the meagre returns that shareholders eventually did receive, 77.4 per cent came from only two of the 38 companies – A-AB and Swan United, the direct successors of both of which were moribund by 1914. Of the 28 companies that were liquidated, 18 returned nothing to shareholders.

Shareholders' experiences can be seen from another perspective. Instead of considering aggregate flows as in Table 1, suppose that a putative electrical investor invested £100, at the first opportunity in 1882, in each of the 38 electrical companies whose shares he could purchase.[30] Such an investment strategy, relative to the issue-weighted one implied in Table 1, would tend to leave the investor over-exposed to successful companies. Table 2a displays the results of this strategy. By the end of 1882, the investor would have lost 9 per cent of his aggregate investment; by the end of 1883, 57 per cent, with losses subsequently mounting. By 1914, the original investment of £3,800 would have returned £714 in cumulated cash dividends

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[28] Ibid.

[29] Only A-AB, the dominant firm in the merger that created Brush Electrical Engineering in 1889, survived until 1914. Investors in other 1882 companies had received through mergers some £72,000 in the securities of the dominant, surviving partner. By 1914, the most valuable were £60,000 in the debentures of Edison & Swan United Electric Light.

[30] One company - Electrical Power Storage (EPS), essentially a patent-pooling entity which issued no shares for cash but only for patents - is excluded from these calculations. Its exclusion does not affect the results for the dividends it eventually received were paltry and all received after 1893. By 1914 the value of the relevant shares was only 30% of initial par.

For companies such as A-AB that had issued shares before 1882, purchase was assumed made on January 7, 1882 (the first quote in 1882). If the first issue of shares was in 1882, it was assumed that the investor paid the issue price. The calculations **do not** assume that dividends were re-invested. As the columns for equity values in Tables 2a and 2b indicate, the security values of surviving firms declined sharply over time and were worth very little by 1914, dividend payments having ceased long before. To assume dividend re-investment would therefore magnify losses. Many of the 38 companies did not have regular price quotations over their entire lifespans. In those cases where quotations were unavailable, we have assumed shares maintained their issue price (or last market quotation) until new information emerged, usually capital write-offs and/or the terms of liquidation or merger.

and liquidation payments; the market value of remaining securities was some £24. Table 2b offers a closer look at the performance of three of the most prominent equipment manufacturers as well the only two supply companies - both small (their aggregated cash investments amounting to some £42,000) – that were profitable investments. No equipment manufacturers ultimately made money for their investors, even neglecting the often-long lag between investment and pay-back. The only positive returns (at a zero discount rate) were achieved by the two small supply companies and the bulk of their returns, ironically, were achieved by the capital gains realized upon being bought by their respective municipalities. Nor was their profitability a fluke: the average internal rate of return earned by the 17 supply companies bought by their local authorities before 1914 was 9.0 per cent, a rate very few other British electrical companies could match. Thus as it turned out, contrary to the fears of predatory compulsory purchase loudly expressed by critics of the 1882 Lighting Act, being bought by a local authority proved to be the most assured route to financial success in the pre-war British electrical industry.

Figure 1 – using the average of bid-ask prices drawn weekly from *The Economist* - plots the course of the 1882 electrical boom and subsequent bust through the experience of three of its most prominent participants, the only ones that had comprehensive runs of price quotations from 1882 onwards: A-AB[31], Hammond Electric Light & Power, and Swan United, benchmarked against an equally-weighted market index consisting of three large railways, three large banks, and three large gas companies. Figure 1 shows, in an otherwise becalmed equity market, the sharp run-up in Brush-Hammond prices between April and June 1882 – some 220 per cent for A-AB and 480 per cent for Hammond - followed by collapse: by end-December 1882, both A-AB and Hammond had lost 80 per cent of their peak values. Swan United, making its market debut just as the Brush pair approached their peaks, never experienced their wild swings, ending the year only 33 per cent below its market peak.[32] None of these price gyrations can be linked to legislative developments. When the first draft of the Electric Lighting bill was published on 3 April 1882, replete with restrictive (presumably threatening) provisions (notably only a seven-year period before companies became exposed to compulsory municipal purchase), the share price of A-AB was rising sharply, soon joined by Hammond. Using standard event study methodology (see MacKinley, "Event Studies"), the weeks following the bill's first draft saw sharply positive – not negative - abnormal returns. Similarly, at the end of May, when the draft bill passed to the Lords after a second reading and with the period of secure tenure raised from

[31] Only the partially paid-up shares issued for cash are plotted. These shares reflect the experience of the general investing public. Because they faced no calls, the fully-paid shares - issued to company insiders for non-cash assets, notably patents, equipment, and brokerage services - were always more valuable and enjoyed markedly higher returns.

[32] Returns are call adjusted. All three companies issued partially-paid shares for cash, but only Swan United made a cash call (of £0.50 on an uncalled liability of £3.00) paid in 1882. In 1883 A-AB enforced cash calls of £4.00 (on an uncalled liability of £6.00), £3.00 having been announced in December 1882. In calculating returns, adjustment is made by increasing the cost basis by the amount of the call. Thus for Swan United, its 1882 peak came at end-September 1882, when its partially-paid shares traded at £2.25 on £2.00 called up, a return on cost of 12.5%. At end-December 1882, when the shares had £2.50 paid up, their mid-market price was £1.875, a return on cost of -25.0%, [=(£1.875/£2.500)-1] and -33.0% from their peak [=(0.750/1.125)-1].

seven to 15 years, abnormal returns the week afterwards were negative, whereas if the length of secure tenure for companies was at issue, the returns should have been positive, reflecting the period of increased security. Then in early June, the shares surged to their all-time peak. And when the bill was finally enacted, on 18 August, with the period of secure private tenure further extended to 21 years, abnormal returns were sharply negative, as they had been since the end of June. While the evidence offered by the event studies is fragile - beta is vanishingly small and statistically insignificant – it offers no support for the claim that the Lighting Act adversely affected Brush-Hammond share prices. They rose and fell without regard to the Act then making its way through Parliament.

Nor did matters improve for Brush-Hammond shareholders subsequently (see Figure 2). Hammond, despite making maximum calls, succumbed to on-going operating losses. The company entered liquidation in 1885 (probably voluntarily), discharging all its debts and eventually returning a small sum to shareholders. A-AB's share price also continued to decline, finally reaching a nadir of £1.00 in January 1884 despite another £4.00 having been called up on the partially-paid shares. A-AB acknowledged market reality in summer 1884, reducing the par values of its shares by between half and five-eighths . In 1884, A-AB's shares began a weak but persistent market recovery, reaching £4.00 on the eve of the merger to form Brush Electrical Engineering in August 1889, aided by the call-up of the remaining £2.00 liability on partially-paid shares.

Swan United's experience was ultimately more rewarding, but only after a tense period in 1884 when its patents were challenged in English courts. In June 1883, in part to avoid a looming patent clash neither wanted in the midst of dull trading, Swan United had merged its British (but not foreign) operations with Edison's English Electric Light to form the Edison & Swan United Electric Light Company (popularly known as "Ediswan"). Since Edison's company had few assets in Britain other than patent rights, its shareholders received 39 per cent of the new company, Swan's the rest. After the merger, Swan United remained an independent company until 1894, when Ediswan absorbed it. From June 1883 onwards, Figure 2 depicts the call-adjusted price evolution of Swan United's shares plus the 0.614 Ediswan share received for each Swan United share held at the time of the merger. Following its eventual English court victory, Ediswan set about vigorously enforcing its monopoly on incandescent lighting in the gradually expanding British lighting market. By the end of 1892, the value of a Swan United share, plus the estimated value of the 0.614 Ediswan shares granted to it, was £5.71.[33] For this, £3.80 had been called up, giving a return on cost of 50 per cent.

[33] Ediswan did not have regular price quotations in the *IMM* until the end of 1895, almost two years after the Edison and Swan patents had expired and a year after a sharp cut in dividends. The appearance of quotes may have been prompted by markedly increased trading volumes as long-time holders, including perhaps both Edison and Swan themselves, sold their shares. In the absence of price quotations for Ediswan shares, we have estimated their value by assuming their (unobserved) market value bore the same relationship to the amount called on the shares as the (observed) market value of Swan United shares bore to their called amounts. Since the dividend streams of the

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Can the Electrical Act or gas competition account for the 1882 electrical boom and bust? No. The bubble inflated and burst without regard to Parliament or competition with gas for lighting markets. It was driven by infatuation with a promising new technology that was driving the rapid growth of a new service – electric lighting. As *The Economist* had noted, the electrical boom was not the first occasion technological infatuation had inflated a bubble, nor would it be the last.[34] Characteristically, the electrical one burst when ignorance and fantasy projections collided with commercial reality, with shareholders belatedly learning the differences between incandescent- and arc-lighting, valuable and worthless patents, and the litigation-intensive distinctions among competing incandescent-lamp filaments, all while bearing the costs of dealing with temperamental new-fangled equipment. Infatuation had enabled A-AB to use its early rapid growth quickly to amass a fabulous cash mountain from the extremely lucrative sale of technology rights. But these sales came to an abrupt and very public end in the early summer of 1882. With brutal clarity, the flaws of its vaunted, premium-priced technology were revealed in the attempt to roll out its system across the country. Even for rudimentary, low-margin arc-lighting, concessionaires were dismayed with the high cost and limited capacity of A-AB dynamos, prompting its most able proponent, Robert Hammond, to turn in desperation in September 1882 – amid crashing share prices - to eighteen-year old Sebastian de Ferranti for a replacement.[35] Worse, in the more lucrative incandescent-lighting market, A-AB had no generator to support its Lane-Fox lamps until 1884, by which time its market capitalization had fallen by 93 per cent and the intrinsic limitations of the Lane-Fox technology were becoming clear.[36] Thus Brush's much-heralded technology, instead of dominating the industry, came to serve as a stark warning against the over-hasty purchases of unproven technologies. In June 1882, just as the Brush bubble was bursting, the chairman of Brush Midland was trying to reassure shareholders - with minimal success (by November its shares were two-thirds below the amount called up in May) - that their company had not overpaid for its Brush concession.[37]

Such mounting complaints highlighted financial manoeuvrings within the Brush group and contrasted badly with the group's faltering technological performance. Following A-AB's lead, many Brush concessionaires had sought to recoup their own expenditures not by creatively deploying the technology they had so expensively bought, but by selling on sub-concessions in their territories in a kind of Ponzi scheme where the losers were those who - like Devon &

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two companies down to 1894 were comparable, this assumption seems reasonable. See Campbell and Turner, "Substitutes", for a discussion of the role of dividends in the determination of Victorian share prices.

[34] In January 1999 *The Economist*, when warning of the likely outcome of the dot.com bubble then rapidly inflating, reprinted its views on the 1882 electrical bubble (quoted above). That warning was soon to be just as vindicated as that of 1882 had been.

[35] Wilson, *Ferranti,* p.15-16.

[36] Byatt, *British Electrical*, pp.19, 141, 186. Byatt, *Electrical Industry*, p. 19. See Bright, *Electric-Lamp*, pp.50, 72 for a discussion of the failings of the Lane-Fox lamp, soon to face competitive elimination. For complaints publicly expressed, see *The Times*, October 2, 9, and 10 1882 (pp.6, 9, 11 respectively).

[37] *The Times*, June 17, 1882, p.13.

Cornwall Electric Light & Power, the first sub-concession to liquidate - purchased a concession, only to discover they couldn't sell sub-concessions in turn.[38] Even A-AB's chairman, Sir Henry Tyler, an MP and former member of the Royal Engineers, at the extraordinary general meeting of shareholders called on August 3 1882 to approve an astonishing 100 per cent dividend, admitted that there had 'been less lighting and more of the sale of sub-concessions than they could have wished', resulting in a 'very unhealthy' situation.[39] A-AB's extraordinary 100 per cent dividend, following one of 12.5 per cent in April, amounted to some £268 thousand, over half the £500.2 thousand it had received from its concessionaires in 1882. Thus cash that concessionaires might reasonably have expected to be dedicated to improving A-AB's imperfect technology and equipment – for example in more urgent work on the company's incandescent-lighting system, more efficient and cheaper generators, more marketing support, and more engineers (from Ohio if necessary) to coax better performance out of unpredictable machinery - was instead spirited out to A-AB's shareholders, to the benefit especially of company insiders holding the fully-paid shares. Nor were the 1882 dividends (never repeated) trivial: at prevailing exchange rates, they amounted to twice the nearly $600 thousand Edison had spent in launching his flagship Manhattan central station.[40] Unsurprisingly, the concessionaires increasingly felt betrayed, with little stomach to struggle on.

In November 1882 *The Economist* argued that the electric light industry as a whole had been discredited by the sharp falls in A-AB's concessionaires.[41] Moreover, concessionaires, having paid so much for technology increasingly revealed as underdeveloped at best, had little left from their initial fund raising to spend on further development, yet could not expect support from A-AB. The most egregious example of this was Metropolitan Brush, also the largest concessionaire, which had raised £297 thousand for the valuable London concession. Of that amount £235 thousand had been spent on buying the concession, leaving only some £62,000 (21 per cent) to buy imperfect equipment and meet operating and marketing costs. In such circumstances, with cash running out and fearful of wasting more, large numbers of electrical companies entered liquidation as losses mounted. However, once money had been spent on technology rights and other sunk costs, logic compelled shareholders to take their chances against all risks to squeeze in the time allotted them whatever they could from the ventures they had rashly embarked upon, **unless** they came to the conclusion that they had made a terrible mistake and that their sunk costs had no value –precisely the conclusion many reached in the effort to escape further losses. Of the 20 supply companies launched on the Stock Exchange by end-1882, 12 (10 of them Brush concessions) were in liquidation before the end of 1885, often voluntarily (including Metropolitan Brush, which could have called up another £200 thousand on its partially-paid shares, had shareholders agreed, which they didn't). A further six survived in some form (including two foreign and two domestic Brush concessions), but not before inflicting swingeing losses on shareholders. Only the two Brush affiliates (both sub-concessions

[38] Devon & Cornwall bought its sub-concession from Great Western Electric Light & Power Company, which entered liquidation two years later.

[39] *The Times*, August 5, 1882, p.12

[40] Passer, *Electrical Manufacturers* , p.118.

[41] *The Economist*, November 4, 1882, p.1368.

of Hammond) that had avoided paying cash for technology rights and were eventually purchased by their municipalities ever earned a positive return for shareholders. Similarly, it should be noted that the foreign supply concessions, beyond the reach of the 1882 Act and facing less vaunted competition from gas, fared just as miserably as their domestic counterparts, and for the same reasons – technology that performed badly.

While the experience of the Brush group was extreme in terms of the amounts of cash raised, transferred and lost, all the electrical companies issuing shares in 1882 struggled in the public glare. No hidden gems rested among the twelve niche engineering companies – they all failed, generally quickly. Jablochkoff's company, fatally burdened by a combination of obsolete and intractable technologies, soon entered voluntary liquidation, shareholders subsequently receiving nothing. Eastern Electric Light & Power, targeting Asia, was in the hands of a London liquidator by 1884, from whom shareholders received nothing. Camille Faúre and his fellow battery inventors fared no better. Their efforts quickly succumbed to high costs, unreliability and lacklustre demand[42], yielding no returns at all to shareholders for the £167 thousand cash invested in Faúre's company and the associated attempt to deploy battery technology the Far East. The Maxim-Weston Electric Company had the benefit of stronger, market-tested technology, but this fleeting advantage (under growing pressure from Edison, Swan, and others) was more than vitiated by remarkably chaotic operating practices, to the extent that Hiram Maxim abandoned it to devise machineguns instead.[43] Lancashire Maxim-Weston Electric Company entered voluntary liquidation in 1884, leaving nothing for shareholders. Amid mounting debts, the parent company followed in 1889, ultimately returning to shareholders 12.0 per cent of the cash it had raised.

The two Edison supply companies survived, but only after heavy losses. Technological difficulties were again the cause. In 1882-4 Edison was fully occupied eliminating the myriad "bugs" in his showcase Manhattan central station, and had neither the time nor resources - he was over-stretched and losing money in New York until 1885 - to tend to his Manchester venture, whose performance suffered accordingly amid general disillusionment and a depressed lighting market.[44] In subsequent years his engineers addressed the problems, benefiting from

[42] Unfortunately for investors in batteries, the most successful incandescent systems, those of Swan and Edison, had little role for them, whereas the Lane-Fox system, which did rely heavily on batteries to regulate voltages, was tied to the fortunes of A-AB, which, lacking a generator for the Lane-Fox lamps, was singularly ill-placed to gain market share. See Passer, *Electrical Manufacturers*, pp.183-84; Parsons, *Early Days*, p.139.

[43] Byatt, *British Electrical*, p.187-88.

[44] Numerous profit-consuming "bugs" appeared after the Pearl Street station began operating in September 1882. For example, to provide adequate and uninterrupted current a means had to be found to operate two generating sets in parallel; insulation was often defective, especially in junction boxes, resulting in an expensive (and dangerous) leakage of current; faulty wiring caused fires. These and other problems were solved and the New York business grew, but it took time, money, and more invention. In 1883 Edison filed the third-largest number of patents in his prolific career (only 1881-82 were greater). Also marketing costs were high: to attract customers, Edison provided free current to lamp purchasers in 1882, resulting in a substantial loss for that year. See Hughes, *Networks*, pp.42, 45.

improved equipment and accumulated experience, but his Manchester company didn't earn its first clear profit until 1887, two years after New York and after the paid-up value of its shares had been written down by half. By 1914, £100 invested in the company's initial public offering in May 1882 would have returned (net of calls) £28 in cumulated dividends; the associated securities (by then Ediswan shares) were worth £1.90. The plight of his Imperial venture was worse. In 1886, it merged (as junior partner, holding a third of the shares), with Brush's greatly diminished Australasian Electric Company, which in turn in 1889 comprised 7.9 per cent of the shares of the reconstructed (and only intermittently profitable) Brush group.

Even Swan United, destined to be the most successful of all the early electrical manufacturers (see Table 2b), experienced technological and operational difficulties in 1882-83. While Swan had an effective incandescent lamp (only Edison's was comparable), the supporting apparatus - the dynamos, cables, switches, fuses, meters, and myriad other items - was in disarray, although R.E.B. Crompton, a talented mechanical engineer turning electrical, was filling the gaps. Yet without an operationally effective lighting system to deploy in the summer of 1882, Swan United was ill-placed to capitalize on the manifold shortcomings of its competitors – he too was confined to small, temperamental lighting sets rather than the large central stations upon which the industry's growth depended.

This brief review of the spectacular 1882 electrical bubble makes clear that distant threats of compulsory purchase from local authorities were irrelevant, as was the threat of competition from a slow-moving gas industry. Technological problems dominated throughout, aggravated by A-AB's dividend effrontery.

Given the market trauma of 1882, it is natural to ask how electrical companies were introduced to British investors. Insight into the flotations comes from 35 abridged prospectuses published in *The Times* between 1880 and 1882 on behalf of those companies seeking the broadest possible market for their shares.[45] Each prospectus named the company's officers, bankers, solicitors, brokers, and auditors, and summarized its business plan. The electrical companies were entirely conventional by the standards of the time. Thirty-three companies had at least one (most had more, including A-AB) 'guinea pig' director (a J.P., M.P., military officer [at least colonel or equivalent rank], baronet, or titled aristocrat). In 34 prospectuses (including A-AB's), at least one director declared outside business interests. Not surprisingly, interconnections by personnel were most prominent among the Brush group. Seven concessions shared a director or technical advisor with A-AB. Eleven shared a director with at least one other Brush concession. There were also 23 vendors (company insiders selling shares to the

[45] Eight of the prospective flotations, all announced after April 1882, appear to have aborted because no further mention of them appears in any of our sources – there is no indication that these eight actually raised any money. No prospectus was published after the electrical bubble burst in June. Interestingly, Swan United, apparently confident of demand for its shares, did not publish an abridged prospectus in *The Times*, whereas A-AB and 13 of its 16 concessionaires did.

general public, distinguishable as those not assuming their directorship till after share allotment) on the boards of 15 companies, among which were A-AB and five of its concessionaires. Many brokers were employed, with the most active, Foster and Braithwaite, servicing A-AB, three of its concessionaires, and the battery company targeting India, upon whose board sat a director of A-AB. Common auditors appeared somewhat more frequently, with Price Waterhouse servicing five firms and Deloitte, Dever, Griffiths, four. Common bankers were also frequent, with Brown, Janson the most prominent (servicing seven firms). Among solicitors only Ingledew & Ince (five firms) and Walter Webb (four firms) served more than a single firm.

The prospectuses were generally confident, with only Hammond warning of looming technological challenges. Most Brush concessionaires claimed (misleadingly) to field both arc- and incandescent-lighting systems and held out the prospect of profits from sub-licensing. Three of ten firms publishing testimonials did so by an advertisement outside the prospectus (and thus not legally binding), one of which was A-AB. The major firms produced lengthy lists of operating installations (predominantly arc lighting). The niche producers intimated that the lighting boom would generate much business for them. Little attention was given to patent costs; despite their importance, only 18 prospectuses revealed them, but these included A-AB, Hammond (who paid no cash), and nine other Brush concessionaires. Estimates of the costs of running lighting systems were generally vague and non-specific – only 20 firms mentioned them at all and of these only a handful (none of them Brush companies) offered concrete detail, with Edison's Indian & Colonial being particularly specific.

Thus the marketing of electrical shares was unexceptional for the time. While electrical companies certainly didn't highlight hazards, many, perhaps most, investors failed to distinguish between arc and incandescent lighting, apparently believing that if a company could field a tried-and-tested arc-lighting system – as A-AB manifestly did – it could field an incandescent one, unaware of the great technological leap required.

IV

The British electrical industry was launched amidst a stock market bubble. But the bubble that formed during the launch of Britain's railways did not prevent it from being for decades the global leader in rail technology, reaping commensurate rewards at home and overseas. Why should the electrical industry have been any different? Part of the answer is that the electrical bubble, unlike the railway one, was not a "useful" bubble.[46] Unlike the railways (or modern fibre-optic cables), the electrical bubble left relatively little useful equipment and

[46] See Eatwell, **"**Useful". He acknowledged (p.46) that bubbles hardly constitute an optimal investment strategy. Moreover, the U.S. and Germany launched highly successful electrical industries without the waste and disruption of a bubble.

infrastructure to pass through liquidation into more capable hands. First, 40 per cent of the money raised by the 1882 companies was spent on technology rights, and of that amount less than a sixth was spent on even remotely competitive technologies. Much of the rest not spent on issuing costs, administration, and premature dividends was spent on obsolete, nearly worthless equipment.[47] Hence neither the rights nor the equipment of liquidated companies were a valuable legacy.[48] Indeed, none of the 1882 British electrical companies were ever profitable for more than brief periods (at best) and the ordinary shares of the three that survived in one form or another to 1914 were by then virtually worthless. Secondly, by the time the indigenous industry emerged from its traumatic start, it persistently lagged behind foreign rivals as technology rapidly evolved. Byatt has argued that after 1895 the British electrical equipment manufacturing industry - where the three largest electrical engineering firms in Britain were wholly-owned subsidiaries of foreign firms - is best regarded as an offshoot of the German and American industries rather than an industry in its own right. [49] Free trade meant there was only a brief window of opportunity for Britain to nurture engineering firms able to compete on equal terms on a global scale. That window effectively closed with the stock market crash of 1882. Britain thus lost an important share in an international growth industry and suffered from being relatively remote from the centres of technological advance and their universities.[50]

Not surprisingly, the 1882 crash greatly suppressed Britain's hitherto vibrant electrical activity, and with it the opportunities for further learning-by-doing that were seized abroad. [51] In the depressed circumstances of 1883, with public scepticism running high as once-vaunted systems floundered and sank, the promising collaboration between Swan and Crompton was interrupted when Crompton undertook to design an ambitious lighting system for the Ring Theatre in far-off Vienna. For his part, Swan husbanded his resources, electing not to make calls of £200 thousand (maximum) on his company's partially-paid shares. Instead, as we have seen, he entered a defensive merger with Edison's English Electric Light. Although the merger strengthened both companies, in the near term it did little to advance the electrical industry in Britain. One of Edison's most experienced engineers had already left London for Berlin and it would be years before the merged company could benefit from Edison's accumulated experience in New York. In 1883, with his New York supply company still losing money, Edison was furiously engaged in making good the weaknesses large-scale operations had exposed in his own system. It would not be until 1886 that he was ready to use his New York

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[47] South-eastern Brush raised £49,000 in cash in 1882. The liquidation of its central station in 1885 returned £345 to shareholders Byatt, (*British Electrical*, p.19).

[48] If the benefits of the 1882 boom were to be found anywhere, it would be in Charles Brush's native Ohio, where he used his share of the cash paid for rights, augmented perhaps by timely sales of the fully-paid A-AB shares he also received, to support his profitable American business, which he sold for $3.3m (£678,000) in 1889 to Thomson-Houston (Passer, *Manufacturers*, pp.53-56) and to use his workshops as a kind of innovation incubator. See Lamoreaux, "Financing Innovation", pp. 48, 78.

[49] Byatt, "Electrical Products", p.273

[50] Reich, "Edison".

[51] Byatt, *British Electrical*, pp.16-18, 139-42. Hughes, *Networks*, pp.61-2. Wilson, *Ferranti*, pp.18-20.

prototype as a model for further expansion.[52] Hugo Hirst, later to be the driving force behind GEC, upon losing his job with Electrical Power Storage in 1884, almost left London to sell small electrical apparatus in Australia.[53]

As well as disrupting existing activity, the bubble caused a sharp reduction in new money flowing into the industry (see Table 3). For a decade after 1882, new money entered at a rate that rarely reached 20 per cent of 1882's level. More seriously, the flow into the engineering sector of the industry – the main source of technical advance – was at a rate that rarely reached 10 per cent of that of 1882.[54] If funds (some £330 thousand) raised between 1883 and 1892 by companies making telegraphic cables are excluded, the proportion is smaller still.[55] And of the £615 thousand raised by non-cable engineering companies, £138 thousand (22.4 per cent) was raised by making calls on shares issued by ill-fated companies in 1882. In short, the large sums raised by electrical engineering companies in Britain before 1883 resulted in surprisingly little capacity, a shortfall not made good in the following decade, by which time General Electric, Westinghouse, AEG, and Siemens were firmly established and would remain dominant in the global electrical engineering industry until well after 1945.

The sudden, unexpected death in 1883 of Sir William Siemens at the early age of 60 amplified the impact of the electrical bubble for British electrical-engineering capability. Hanoverian-born Sir William, whose British residency testified to the country's attractiveness for talented foreigners, shared with his elder brother Werner both remarkable inventive ability and a keen interest in the evolving applications of electricity, as exemplified by his role in 1866 in the invention of a self-exciting dynamo; by his establishment in 1881 of Britain's first public central station in Godalming, Surrey; and by his construction at Portrush in 1883 of one of Britain's earliest electric railways.[56] He was personally wealthy, highly respected, and led a financially strong company. Had he lived, given his career, it is reasonable to suppose that he would not have been deterred by the technological confusion and heightened risk aversion that reigned in the wake of the burst bubble.[57] Moreover, he was in an excellent position to monitor electrical developments around the world, not least those in Germany where his brother was then joining with Emil Rathenau to exploit, and later extend, the Edison patents. But upon Sir William's death, control of the British branch of the family business passed decisively to Werner in Berlin, who decreed that it should concentrate on its highly profitable underseas telegraph

[52] Hughes, *Networks*, pp.42-46, 82-84. Edison would not disclose the operating costs of his Pearl Street station for several years, until he finally deemed them presentable. Hughes, *Networks*, pp.69-73.

[53] Jones & Marriot, *Anatomy*, p.72.

[54] The most profitable British electrical engineering firms didn't emerge until long after 1882: GEC and C.A. Parsons (1889); British Insulated Wire (1890); Callender's Cable (1896).

[55] With the important exception of Siemens Brothers, the companies making underseas telegraph cables before 1880 played little role in the electrical industry.

[56] On the dynamo invention, see Scott, *Siemens Brothers*, p.46. On electric railways, see Byatt, *British Electrical*, pp.30 .

[57] Regarding technological confusion and heightened risk aversion, see Robert Hammond's views, quoted in Wilson, *Ferranti*, pp.21-2.

cables business. Hence Siemens' Brothers ceased work on incandescent lighting, traction and other electrical projects in 1883-4. It would not be until the mid-1890s, when Berlin responded to the growing backwardness of British electrical engineering practice, that Siemens Brothers would once again engage in the full range of electrical engineering activities.

The blow received in 1882 by the British electrical engineering industry had important consequences for the subsequent evolution of the electrical supply (utilities) industry. A slow recovery can be dated from early 1884, when the shares of A-AB reached their nadir. Recovery was based on the resumed installation of so-called isolated stations, a few of the larger ones supporting hundreds of lamps, each driven by a small generator providing incandescent lighting to small groups of users (in homes, clubs, restaurants, etc.) in affluent areas, as well as arc-lighting for industrial purposes. While the debacle of 1882 had halted ambitious central station construction requiring the large front-loaded expenditures that A-AB had once aspired to and Edison had achieved (with difficulty) in New York, the sorts of limited installations that had been made before 1882 continued, albeit at a temporarily reduced level. [58] Unlike central stations serving many thousands of lamps, the costs of constructing these isolated installations were low, affordable by wealthy individuals without the need for external finance. As experimentation proceeded and equipment (increasingly imported) improved, these limited lighting installations gradually became larger, more capable, and above all, more reliable, with entire blocks of flats in well-heeled neighbourhoods clubbing together to acquire an electricity supply (mostly direct current). Costs per user fell as the fixed costs of installation became more widely shared. Many of Britain's first successful central-station supply companies, appearing in the later 1880s and early 1890s, had their origins in London's 'lighting clubs', including Kensington & Knightsbridge Electric Lighting (from Crompton's private supply to his home in Kensington Court), London Electricity Supply (LESCo, from Sir Coutts Lindsey's Grosvenor Gallery in New Bond Street, for which Sebastian Ferranti was chief engineer), and Metropolitan Electric Supply (from the private supply at Whitehall Court).[59]

This evolution, in which small isolated installations for lighting remained, for much longer than in the U.S. or Germany, the principal route by which electricity supply expanded and out of which the first successful central stations grew, meant that Britain's successful engineering companies, such as GEC, expanded in the wake of the large lighting-orientated central-station companies rather than driving them and diversifying demand in the process, as Edison and his rivals were doing in the U.S. and Germany. Edison, like the Siemens brothers,

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[58] Whereas A-AB's equipment sales fell by some 82% in 1883, Siemens', untainted by exaggerated expectations, declined only modestly, while Crompton's grew strongly. Byatt, *British Electrical*, pp.17-19, 141-42.

[59] Parsons, *Early Days*, pp.21-25, 71-95; Byatt, *British Electrical,* p.25. Nor were many of these companies deterred by the 1882 Act. Altogether ten electricity supply companies had registered with the Stock Exchange and had either begun operations or were actively preparing to do so between the beginning of 1883 and the passage of the amending Act in June 1888. If legislation had been as feared as conventional wisdom maintains, the vagaries of the Parliamentary timetable and its vulnerability to unpredictable events (in Ireland, say), would have precluded investment until the 1882 Act had been safely amended.

but unlike the London lighting pioneers, was keenly aware of the possibilities of using electricity to power trains and trams, having built a test track, as had Werner Siemens, as early as 1879. He realized that by finding more uses for electricity he could profitably lower prices for elastically-demanded current. He also knew that there were not enough wealthy districts to satisfy his ambitions; hence rapid expansion would require new uses and lower electricity prices. Although Edison himself never brought his traction ideas to fruition, in 1887-88 one of his former employees, Frank Sprague, did, drawing on both financial and manufacturing support from within the then-rapidly expanding Edison organization. Sprague's success with his electric-tram system was eagerly seized upon by the proliferating Edison companies (and by those of his more capable rivals) as a means of using existing generating equipment more efficiently, thus lowering costs and prices. Further experimentation led to other power applications, especially in factories. Germany followed rapidly, innovating as it went. But Britain, especially London, lagged, and electricity prices remained demand-killingly high there.

The trend-setting London 'lighting clubs' simply did not evince the same urgency to find new markets for electricity. The first British company that did was Newcastle Electric Supply Company (NESCo), established in 1889, but for more than a decade was less influential than the London companies.[60] The London companies thus set a "style" for British electrification. Since many had emerged from the efforts of individual engineers to provide lighting for themselves and a few close neighbours, there was no standardization among them. Indeed, differences in equipment and practice were often a mark of craft pride. The chief engineers of two of the London companies - Ferranti at LESCo and Crompton at Kensington & Knightsbridge – had, like Edison, large-scale manufacturing aspirations, which, had they been successful would have brought to their follow-up central stations some of the same coherence and economies of scale in manufacture that Edison brought to his. But their aspirations were still-born - Ferranti because he seriously over-reached himself with his ambitious Deptford scheme and Crompton because he completely misjudged market and technological trends.[61] Their failures in the early 1890s removed at a crucial juncture any impetus towards greater uniformity of practice in terms of currents, frequencies, voltages, and distribution systems. In the absence of equipment manufacturers marketing more-or-less standardized systems on a large scale, aided by the relatively low prices mass production afforded and the ability to extend vendor finance, consulting engineers came to play a much larger role in technological choice in Britain than in either the U.S. or Germany. Capable consulting engineers, intermediating creatively between manufacturers and end-users (usually supply undertakings), could achieve outstanding results, as Charles Merz was to prove at Newcastle. But the effectiveness of the consulting engineer depended upon the brief he was given. When the brief was unambitious, as it often was when issued by local authorities haunted by the spectre of 1882 and wary of anything that might smack of technological adventurism, even good consulting engineers were constrained to deliver safe but unambitious projects. Moreover, consulting engineers lacked the financial clout and research capabilities that the large electrical manufacturers in the U.S. and Germany soon came

[60] Hughes, *Networks*, pp.227-232, 250.

[61] Byatt, *Electrical*, pp.100-105; 190-191.

to acquire, enabling them to 'push' ambitious schemes.[62] Merz' unique effectiveness at Newcastle depended on unique circumstances – a remarkable coincidence of technical talent, wealth, and family connections – his scientifically-trained father, of German background, was president of one of Newcastle's supply companies, while an uncle was one of Tyneside's largest shipbuilders and unusually receptive of innovative ideas.[63] In less propitious circumstances, consulting engineers were much less effective in promoting technological advance than were large, financially strong manufacturers able to wield technological and political influence, as Merz' own unhappy experience in London was to prove.[64] Thus the idiosyncratic preferences of the chief engineers of individual companies prevailed, especially in London, which, Newcastle aside, dominated British electrical practice. In many ways, the false start of 1882 cast a long shadow.

V

The 1882 electrical bubble inflated without regard to regulation (or anything else), and burst with the first brush with reality. The exaggerated threat of municipal near-confiscation 21 years in the future paled beside the mounting losses that threatened imminent bankruptcy for most would-be supply companies, especially where large cash expenditures on near-worthless technology rights left them with little to spend on marketing and other start-up costs. While the bursting of the electrical bubble had little immediate impact on the British macro-economy, it radically slowed electrical investment and experimentation at a time of technological ferment and delayed for a decade the effort to move beyond lighting. The financial drama of 1882 produced no sustainably profitable companies. In an industry where early-mover advantages were significant, this flawed launch left long-lasting disadvantages. Further scarred by Ferranti's ill-fated venture at Deptford, the British electrical engineering industry of 1890 was caught in a time-warp, focusing mainly on relatively small-scale, idiosyncratic lighting schemes lacking economies of scale in manufacture, and missing entirely the moves to large-scale polyphase transmission and emerging power applications.

In retrospect, there appears to have been no plausible quick and effective response to the electrical boom and bust of 1882.[65] Over a century later, more sophisticated capital markets still experience dangerous bubbles that leave subdued economic activity in their wake.[66] It is facile and misguided to suggest that regulation caused either the crash or the post-crash malaise in the British electrical industry. It also obscures lessons that might be drawn from the experience. It

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[62] Edison had financial clout from the start, having secured the backing of J.P. Morgan in 1878.

[63] Hughes, *Networks*, 448-449.

[64] Hughes, *Networks*, pp.250-254.

[65] Protection doesn't qualify, even if it had had political support (which in the 1880s it didn't). As the Victorians understood (and the experience of the 1930s was to show), it would have made British electrification more expensive, less effective, and even slower.

[66] See generally Shiller *Irrational Exuberance; The Economist* (October 9, 2010), Special report on the world economy:'The cost of repair', pp.14-17.

is easy to hope that governments might be wise. But making new technology work acceptably is notably harder, and often requires, as electrical engineering did, financial strength matched equally with financial discipline. It was Britain's misfortune then that its relatively advanced capital markets fully exposed the fledgling industry to market volatility without also affording it the resilience of a seasoned venture-capital sector, able to bear intrinsic risks while still pursuing promising opportunities. It was also unfortunate that so many purchases of technology in 1882were not incentive-compatible: had less cash and more shares been paid, more cash would have been available to develop the fledgling technology, thus perhaps eventually making the shares themselves more valuable.

All this is not to claim that the 1882/88 Acts were completely irrelevant. They did indeed contain flaws, but these became manifest only gradually over time and were not germane to the malaise of the industry's first decade, during which time it became permanently backward by global standards. The Acts enabled municipalities, prone to be cautious anyway, to be obstructionist if they wished, allowing them to impede private projects even if they chose to do nothing, and, if they did provide a supply, shielding them from pressure to lower prices. But this was not a problem in the 1880s: municipal obstruction did not prevent the launch in 1882 of more supply schemes than the market could effectively scrutinize, nor did it stop scores of companies successfully going public from 1887 onwards. Nor did it stop foreign direct investment from flooding in. A more serious failing was that until 1898 the Act restricted supply companies to the tight confines of municipal boundaries. While this would not have been so harmful had DC systems remained as dominant as they were in 1882, the situation became progressively more pernicious with the growing embrace of AC technology, which required ever-widening service areas in order to realize ever-greater economies of scale. But whatever problems ultimately flowed from the 1882 Lighting Act, the Stock Exchange debacle of that year and its attendant woes were not among them.

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Table 1. Main technological groupings						
		1.	2a.	2b.	3.	4.
Company (Date of creation)		Total cash raised by ordinary share issue before end-June 1914 (in 1882 only)	Cash paid for patents	Nominal value of ordinary shares issued for patents (fully paid unless otherwise noted)	Total cumulated cash pay-outs received by holders of ordinary shares through end-June 1914	Date of termination or value at end-June 1914
1.	Anglo-American Brush Electric Light Corporation (December 1880)	£273,918 [1] (£80,997 [2])	£132,950 [3]	£143,750	£421,586 [4,5]	£9,809 [6]
1A.	Brush domestic concessions: 12 companies (See Appendix Table 1A for details.)	£950,345 (£878,526)	£403,200	£200,350	£125,488 [7]	None remaining as independent companies. (See Appendix Table 1A for details.)
1B.	Brush foreign concessions: 4 companies (See Appendix Table 1B for details.)	£313,181 (£227,839)	£97,000	£114,000	£24,835 [7,8]	None remaining as independent companies. (See Appendix Table 1B for details.)
2.	Swan United Electric Light Company (19 May 1882)	£280,875 (£200,625)	£122,000	£98,750	£514,127 [9]	Merged with Edison and Swan United Electric Light (Ediswan) in 1894.
Page Totals		£1,818,319 (£1,387,987)	£755,150	£556,850	£1,086,036	£9,809

1. Sum excludes £92,555 cash raised by successor company, Brush Electrical Engineering (BEE), after 1889. 2. Calls of this amount were made late in 1882, but the cash was collected in early 1883. 3. This was the amount written off at the end of 1882 from the value of patents purchased. 4. Includes £150,141 of dividends paid on the 52,314 BEE shares (preference and ordinary in equal numbers) issued to acquire all of Anglo-American Brush's (A-A B) ordinary shares in 1889, of which £81,915 was paid on shares originally issued to cash buyers. 5. Dividends of £267,757 were paid in 1882, of which £121,496 was paid to the holders of partially-paid shares. 6. End-June 1914 market value of the 52,314 BEE shares (preference and ordinary in equal numbers) issued to acquire all of A-A B's ordinary shares in 1889. 7. Excludes the cumulated dividends and end-June 1914 market values of the 7,545 BEE securities (preference and ordinary equally) exchanged for the 7,545 A-AB shares issued before 1889 to acquire the ordinary shares originally issued by concessions (two domestic and one foreign); these dividends (£21,654) and market values (£2,446), of which 83% arose from domestic concessions, are included with the A-A B totals. 8. Excludes the end-June 1914 market value of the 5,500 BEE shares (preference and ordinary equally) issued in 1889 to acquire all the shares originally issued by Australasian Brush, amounting to £1,031. 9. Includes £257,444 dividends (Swan United's share of Edison & Swan United [Ediswan] ordinary dividends) plus £87,750 interest on Ediswan debentures from 1894. The end-June 1914 market value of Ediswan debentures issued in 1894 in exchange for all outstanding ordinary shares of Swan United, £60,000, is excluded.

Table 1 [con't.] Main Technological Groupings						
		1.	2a.	2b.	3.	4.
Company (Date of creation)		Total cash raised by ordinary share issue before end-June 1914 (in 1882 only)	Cash paid for patents	Nominal value of ordinary shares issued for patents (fully paid unless otherwise noted)	Total cumulated cash pay-outs received by holders of ordinary shares through end-June 1914	Date of termination or value at end-June 1914
3.	Battery Grouping [1] (All January/February 1882)	£166,929 [2] (£159,429)	£75,000 [3]	£854,800 [4]	£23,376 [5]	Fauŕe: voluntary liquidation by 1884. I&O: in liquidation, 1885. EPS: merged with Electric Construction Corporation in 1889.
4.	Maxim-Weston Electric Company (1 April 1881)	£131,575 (£10,000)	£113,820	£12,500	£22,923 [6].	In liquidation, 1889.
4A.	Lancashire Maxim-Weston Electric Company. (19 September 1882)	£24,038 (£24,038)	£10,000 [7]	£10,000 [7]	Nil.	In voluntary liquidation, 1884.
Page Totals		£322,542 (£193,467)	£198,820	£877,300	£46,299	

1. Fauŕe Electric Accumulator Co.; Electrical Power Storage Co. (EPS); Indian & Oriental Electrical Storage & Works Co (I&O). 2. Of which: Fauŕe, £99,429; EPS raised no cash publicly; I & O, £67,500;. 3. Of which: £25,000 paid to Camille Fauŕe; EPS, nil; £50,000 paid by I & O. 4. Of which: £300,000 issued to Camille Fauŕe; £529,800 issued by EPS; £25,000 issued by I & O. 5. EPS's share of cumulated ordinary dividends paid by Electric Construction Corporation (ECC) after merger in 1889. The amount excludes the end-June 1914 market value of ordinary shares issued by ECC in exchange for all of EPS's upon merger in 1889, £9,797. There were no payouts made by the other two companies. 6. Dividends: £6,748; liquidation payments: £16,175. 7. Paid to Maxim-Weston Electric.

Table 1 [con't.] Main Technological Groupings						
		1.	2a.	2b.	4.	5.
Company (Date of creation)		Total cash raised by ordinary share issue before end-June 1914 (in 1882 only)	Cash paid for patents	Nominal value of ordinary shares issued for patents (fully paid unless otherwise noted)	Total cumulated cash pay-out received by holders of ordinary shares through end-June 1914	Date of termination or value at end-June 1914
5A.	Manchester & District Edison Electric Light Company (23 May 1882)	£50,000 (£40,000)	£25,000	£100,000 [1]	£20,150 [2]	Merged with Ediswan in 1896.
5B.	Edison's Indian & Colonial Electric Company (13 June1882)	£61,230 (£61,230)	£25,000	£75,000 [3]	£4,720 [4]	Merged with Australasian Brush in 1886, which in turn became part of Brush Electrical Engineering Company in 1889.
6.	Eastern Electric Light & Power Company (15 July 1882)	£102,921 (£63,021)	£23,759	£45,500	Nil.	In liquidation in London in 1884.
Page Totals		£214,151 (£164,251)	£73,759	£220,500	£24,870	

1. "B" class (subordinate) ordinary shares issued to Edison. 2. £7,750 dividends paid on Manchester Edison ordinary shares plus £12,400 cash dividends paid by Ediswan to holders of the 10,000 Ediswan ordinary shares exchanged for all 20,000 of Manchester Edison's in 1896. Excludes end-June 1914 value of the 10,000 Ediswan shares received in exchange for Manchester Edison's in 1896, amounting to £625. 3. £50,000 "B" class (subordinate) ordinary shares issued to Edison, plus £25,000 "A" class. 4. Dividends paid by Brush Electrical Engineering on shares issued in 1889 in exchange for those of Australasian Brush which had been issued in exchange for all those of Edison's Indian & Colonial in March 1886. Excludes end-June 1914 value of those shares, amounting to £308.

Table 1 [con't.] Main Technological Groupings						
		1.	2a.	2b.	4.	5.
Company (Date of creation)		Total cash raised by ordinary share issue before end-June 1914 (in 1882 only)	Cash paid for patents	Nominal value of ordinary shares issued for patents (fully paid unless otherwise noted)	Total cumulated cash pay-out received by holders of ordinary shares through end-June 1914	Date of termination or terminal value at end-June 1914
7.	Jablochkoff Electric Light & Power Company (18 May 1882)	£94,804 (£94,804)	£50,000	£100,000	Nil	In voluntary liquidation by 1884.
8.	"The Rest" 12 companies (See Appendix Table 1C for details)	£577,584 (£512,022)	£131,860	£388,090	£69,358	None survived in any form to 1914. See Appendix Table 1C for details.
Page Totals: 2 groups		£672,388 (£606,826)	£181,860	£488,090	£69,358	Nil
Grand total: 8 groups		£3,027,400 (£2,352,531)	£1,209,589	£2,142,740	£1,226,563	£9,809

Table 2a: Return on investment of £100 in each company raising cash in 1882 (excluding brokerage)

Valuation of:	All firms Total return a,b	All firms Equity value only	Supply firms Total return a,b	Supply firms Equity value only	Equipment firms Total return a,b	Equipment firms Equity value only
No. of firms	38	38	20	20	18	18
Initial investment (£)	£3,800	£3,800	£2,000	£2,000	£1,800	£1,800
Initial investment (%)	100%	100%	100%	100%	100%	100%
End 1882	91%	90%	87%	87%	95%	93%
End 1883	43%	39%	45%	43%	41%	35%
End 1884	36%	33%	43%	42%	29%	23%
End 1890	18%	12%	19%	15%	17%	9%
End 1900	22%	4%	31%	5%	12%	3%
End 1910	19%	< 1%	27%	0%	11%	< 1%
End June 1914	19%	< 1%	27%	0%	11%	< 1%

a Total Return is market value (or last issue price if no quote is available) at indicated date plus cumulated dividends paid from January 1882 minus all subsequent calls on partially-paid shares issued in 1880-82.

b Shares purchased for cash only

Table 2b: Return on investment of £100 in selected companies raising cash in 1882 (excluding brokerage)

	(1) Engineering firms in 1882 with weekly quotes						(2) Municipal purchases	
	A.-A. Brush 1		Hammond 1		Swan United a,b			
Valuation of:	Total return c	Equity value only	Total return c	Equity value only	Total return c	Equity value only	Total return c	Equity value only
No. of firms	1	1	1	1	1	1	2	2
Initial investment (£)	£100	£100	£100	£100	£100	£100	£200	£200
Initial investment (%)	100%	100%	100%	100%	100%	100%	100%	100%
End 1882	83%	67%	135%	135%	70%	70%	100%	100%
End 1883	32%	26%	90%	90%	113%	113%	100%	100%
End 1884	26%	21%	0% d	0% d	6%	6%	100%	100%
End 1890	8%	8%	0%	0%	68%	60%	106%	100%
End 1900	40%	26%	0%	0%	55%	21%	198%	0%
End 1910	19%	1%	0%	0%	45%	5%	198%	0%
End June 1914	20%	2%	0%	0%	46%	4%	198%	0%

a Shares purchased for cash only.

b Includes 0.61 ordinary share of Edison and Swan United Electric Light with each ordinary share of Swan United after their merger in October 1883.

c Total Return is market value (or last issue price if no quote is available) at indicated date plus cumulated dividends paid from January 1882 minus all subsequent calls on partially-paid shares issued in 1880-82.

d Since Hammond's cumulated dividends and market value were insufficient to meet the cash call in 1884, we assume shareholders abandoned the shares as worthless. To have met the call would have made the eventual loss (the firm was liquidated in 1885) exceed £100, the hypothetical investment limit.

Table 3 Cash raised through the issue of ordinary shares by British electrical companies, 1880-1892								
	(1) Total gross cash amount raised by year (all electrical companies) £ '000	(2) Col. (1) as % of 1882 issue	(3) Total cash raised by electrical engineering companies through issues of ordinary shares, including calls £ '000 (as % of 1882 amount)		(4) Total cash raised by electrical engineering companies through new issues of ordinary shares, excluding calls £ '000 (as % of sterling amount in Col. (3))		(5) Calls on shares issued in 1882 or earlier (all electrical companies) £ '000 (as % of Col. (1))	
1880	£483	20.5%	£483	(46.3%)	£483	(100.0%)	£483	(100.0%)
1881	£153	6.5%	£122	(11.7%)	£122	(100.0%)	£153	(100.0%)
1882	£2,353*	100.0%	£1,043	(100.0%*)	£952	(91.3%)*	£2,353	(100.0%)*
1883	£199	8.5%	£139	(13.3%)	£77	(52.8%)	£72	(36.2%)
1884	£160	6.8%	£83	(8.0%)	£2	(2.4%)	£157	(98.1%)
1885	£261[a]	11.1%	£246 [a]	(23.6%)	£206 [a]	(83.7%)	£40	(15.3%)
1886	£49	2.1%	£19	(1.8%)	£19	(31.6%)	£9	(18.4%)
1887	£462	19.6%	£82	(7.9%)	£53	(64.6%)	£42	(9.1%)
1888	£457	19.4%	£58	(5.6%)	£58	(100.0%)	£0	(0.0%)
1889	£455	19.3%	£142	(13.6%)	£64	(45.1%)	£26	(5.7%)
1890	£483	20.5%	£3	(0.3%)	£3	(100.0%)	£0	(0.0%)
1891	£681	28.9%	£46	(4.1%)	£34	(73.9%)	£0	(0.0%)
1892	£477 [b]	20.3%	£129 [b]	(12.4%)	£129 [b]	(100.0%)	£0	(0.0%)
Totals 1883-1892	£3,684	156.6%	£947	(90.8%)	£629	(17.0%)	£346	(9.4%)

*Calls announced in 1882 are included in the 1882 Row, even if the call was actually paid in 1883.

a. £206,000 raised by cable manufacturers then focused almost entirely on telegraphy.

b. £126,000 of the £129,000 raised was for a telegraph cable manufacturer only remotely connected with the electrical engineering industry.

Table 1A Brush Domestic Affilates								
		1.	1a.	2.	3.	3a.	4.	5.
Company (Date of creation)		Total cash raised by ordinary share issue to end-June 1914	Of which: cash raised in 1882	Total nominal value of ordinary shares issued before end-June 1914	Cash paid for Brush patents	Nominal value of ordinary shares issued for patents (fully paid unless otherwise noted)	Total cumulated cash pay-outs received by holders of ordinary shares through end-June 1914	Date of termination or value at end-June 1914
1.	Birmingham and Warwickshire Brush Electric Light Company, Ltd. (Jan/Feb 1882)	£75,000	£75,000	£100,000 Never quoted in *IMM*.	£15,000	£25,000	(£535) [1]	Taken over by Hammond Electric in a share swap (no cash), 10 November 1883.
2.	Brush Electric Light and Power Company of Scotland, Ltd. (Jan/Feb 1882)	£55,000	£55,000	£95,000 Peak market value, £38,500, August 1882.	£15,000	£40,000	£13,750 [2]	Voluntary liquidation under court supervision, 3 November 1883.
3.	Brush Midland Electric Light and Power Company, Ltd. (Jan/Feb 1882)	£41,800	£41,800	£59,800 Never quoted in *IMM*.	£25,700	£18,000	(£7,812) [3]	Taken over by Anglo-American Brush in a share swap (no cash) in early 1885
4.	Devon and Cornwall Electric Light and Power Company, Ltd. (12 May 1882)	£45,375	£45,375	£54,625 Never quoted in *IMM*	£10,500 [4]	£9,250	Nil	Voluntary liquidation begun Jan. 1883. [5]
Page Totals (4 companies)		£217,175	£217,175	£309,425	£66,200	£92,250	£13,750	

1. Paid on 3,566 shares in Hammond Electric Light and Power. (This cash payment is included in the total for Hammond given below and excluded here). 2. Cash from liquidation; there were no dividends. Value estimated from the last quote in the *IMM* days before liquidation. 3. £212 in cash dividends from 2,648 Anglo-American. Brush ordinary shares plus £7,600 cash dividends from shares of Brush Electrical Engineering issued upon merger in 1889. (This cash payment is included in the total for Anglo-American Brush in Table 1 and excluded here). 4. Paid to Great Western Electric (see Row 6) for Brush concession. 5. The first Brush affiliate to enter liquidation.

Table 1A [con't.] Brush Domestic Affiliates								
		1.	1a.	2.	3.	3a.	4.	5.
Company (Date of creation)		Total cash raised by ordinary share issue before end-June 1914	Of which: cash raised in 1882	Total nominal value of ordinary shares issued before end-June 1914	Cash paid for Brush patents	Nominal value of ordinary shares issued for patents (fully paid unless otherwise noted)	Total cumulated cash pay-outs received by holders of ordinary shares through end-June 1914	Date of termination or value at end-June 1914
5.	Eastbourne Electric Light Company, Ltd. (15 Feb. 1882)	£20,809	£10,250	£19,090 Never quoted in *IMM*.	Nil	£2,050 [1]	£44,305 [2]	Purchased by Local Authority in December 1899.
6.	Great Western Electric Light and Power Company, Ltd. (30 March 1882)	£55,000	£55,000	£70,000 Peak market value, £33,000, October 1882.	£20,500	£15,000	£12,500 [3]	Assets acquired by Anglo-American Brush during liquidation in early 1885.
7.	Hastings and St. Leonard's-on-Sea Electric Light Co., Ltd. (7 March 1882)	£21,220	£5,000	£27,220 Never quoted in *IMM.*	Nil	£6,000 [4]	£38,402 [5]	Purchased by Local Authority in July 1898.
8.	Hammond Electric Light and Power Co., Ltd. (Jan/Feb 1882)	£89,990	£44,950	£125,090 Peak market value, £368,590, May 1882.	Nil	£35,100 [6]	£11,531 [7]	Liquidation begun 1885; final pay-out, 1887.
9.	Metropolitan (Brush) Electric Light and Power Company, Ltd. (16 May 1882)	£297,549	£297,549	£297,549 Peak market value, £24,796, Oct. 1883 [8]	£235,000 [9]	None	Nil	Voluntary liquidation in 1884.
Page Totals (5 companies)		£484,568	£412,749	£538,949	£255,500	£58,100	£106,738	

1. Minimum; issued to Hammond Electric on same terms as Hastings (see Row 7 below). 2. Of which £6,125 were dividends, the remainder cash paid by Local Authority. 3. No dividends, cash from liquidation only. The total omits £291 in cash dividends from 3,633 Anglo-American Brush ordinary shares plus £10,427 cash dividends paid on shares of Brush Electrical Engineering, both of which are included in Table 1 for Anglo-American Brush. 4. 20% of issued shares, capped at £6,000. 5. Of which £6,498 were dividends, the remainder cash paid by Local Authority. 6. Includes 20 Founder's shares (£100). 7. Of which £3,998 were dividends, the remainder liquidation proceeds. 8. Only quote in *IMM*. 8. £215,000 paid to Anglo-American Brush and £20,000 to Hammond Electric Light and Power.

Table 1A [con't.] Brush Domestic Affiliates								
		1.	1a.	2.	3.	3a.	4.	5.
Company (Date of creation)		Total cash raised by ordinary share issue before end-June 1914	Of which: cash raised in 1882	Total nominal value of ordinary shares issued before end-June 1914	Cash paid for Brush patents	Nominal value of ordinary shares issued for patents (fully paid unless otherwise noted)	Total cumulated cash pay-out received by holders of ordinary shares	Date of termination or value at end-June 1914
10.	Provincial (Brush) Electric Light and Power Company, Ltd. (16 May 1882)	£49,602	£49,602	£49,602 Never quoted in *IMM*.	£22,500	Nil	Nil	Liquidated in 1884.
11.	South Eastern (Brush) Electric Light and Power Company, Ltd. (Jan/Feb 1882)	£49,000	£49,000	£51,000 Never quoted in *IMM.*	£9,000	£2,000	Nil	Liquidated in 1885.
12.	Yorkshire (Brush) Electric Light and Power Company, Ltd. (Jan/Feb 1882)	£150,000	£150,000	£200,000 Never quoted in *IMM.*	£50,000	£50,000	(£673) [1]	Absorbed by Hammond Electric via a share swap (no cash) 10 Nov. 1883.
Page Totals (3 companies)		£248,602	£248,602	£300,602	£81,500	£52,000	Nil	
Grand total: 12 companies		£950,345	£878,526	£1,148,976	£403,200	£200,350	£120,488	
1. Yorkshire Brush's shareholders' portion of cash distributed upon the liquidation of Hammond Electric. (This sum is included with the total for Hammond Electric and excluded here.)								

TABLE 1B. Summary of the Financial Experience of Brush Foreign Affiliates

		1.	1a.	2.	3.	3a.	4.	5.
Company (Date of creation)		Total cash raised by ordinary share issue before end-June 1914	Of which: cash raised in 1882	Total nominal value of ordinary shares issued before end-June 1914	Cash paid for Brush patents	Nominal value of ordinary shares issued for patents (fully paid unless otherwise noted)	Total cumulated cash pay-outs received by holders of ordinary shares through end-June 1914	Date of termination or value at end-June 1914
1.	Anglo-Spanish (Brush) Electric Light & Power Company, Ltd. (18 May 1882)	£26,721	£26,721	£ 62,721 Never quoted in *IMM*.	[£14,000?] [1]	£36,000	Nil	In liquidation, 1885 [2]
2.	Australasian Electric Light, Power & Storage Company, Ltd. (11 May 1882)	£118,674	£72,000	£235,856 Peak market value: £69,750, Sept 1882.	£45,000	£35,000	£11,064 [3]	£1,031 [4]
Page Totals: 2 companies		£145,395	£98,721	£304,322	£45,000 [1]	£66,000	£11,064	£1,031

1. Anglo-Spanish Brush never completed its cash calls before entering liquidation. Hence the maximum cash payment of £14,000 for patents may never have been paid and is not included in the totals, although some lesser payment was probably made. 2. Unusually, *Burdett's* did not (perhaps could not) identify the liquidator or place of liquidation. 3. Cash dividends paid by Brush Electrical Engineering (BEE) on the original Australasian shares (i.e. excluding those issued to acquire Edison's Indian & Colonial Electric in 1886) exchanged in August 1889 for 5% of the issue of new BEE shares (ordinary and preference equally). 4. End-June 1914 value of BEE shares issued to the holders of the original Australasian ordinary shares.

TABLE 1B [con't.]. Summary of the Financial Experience of Brush Foreign Affiliates								
		1.	1a.	2.	3.	3a.	4.	5.
Company (Date of creation)		Total cash raised by ordinary share issue before end-June 1914	Of which: cash raised in 1882	Total nominal value of ordinary shares issued before July 1914	Cash paid for patents	Nominal value of ordinary shares issued for patents (fully paid unless otherwise noted)	Total cumulated cash pay-outs received by holders of ordinary shares	Date of termination or value at end-June 1914
3.	International Electric Company, Ltd. [1] (13 June 1882)	£118,672	£80,004	£166,672 Never quoted in *IMM*.	£27,000	£48,000 [2]	(£3,628) [3]	In voluntary liquidation under court supervision in London in 1886.
4.	South African "Brush" Electric Light & Power Company. Ltd. (Jan/Feb 1882)	£49,114	£49,114	£49,114 Peak market value: £25,000, October 1882.	£25,000	None	£13,771 [4]	Liquidation in London began in 1885; last pay-out 4 March 1886.
Page Totals: 2 companies		£167,786	£129,118	£215,786	£52,000	£48,000	£13,771	Nil
Grand Total: 4 companies		£313,181	£227,839	£520,108	£97,000	£114,000	£24,835	£1,031

1. Originally registered as Anglo-Austrian Brush Electrical Company; named changed in December 1882. 2. Unusually, 8,000 ordinary shares (each £5 nominal, amounting to £20,000) were issued only half paid-up in exchange for patent rights; a further 5,600 ordinary shares were issued fully paid. 3. These dividends were eventually paid on shares issued by Anglo-American Brush in exchange for assets acquired from liquidator. The £3,628 is included with Anglo-American Brush's pay-out total in Table 1, and is excluded here to avoid double counting. 4. Liquidation proceeds only; no dividends.

Table 1C Summary of the Financial Experience of "The Rest"								
		1.	1a.	2.	3.	3a.	4.	5.
Company (Date of creation)		Total cash raised by ordinary share issue before end-June 1914	Of which: cash raised in 1882	Total nominal value of ordinary shares issued before end-June 1914	Cash paid for patents	Nominal value of ordinary shares issued for patents (fully paid unless otherwise noted)	Total cumulated cash pay-outs received by holders of ordinary shares through end-June 1914	Date of termination or value at end-June 1914
1.	Gülcher Electric Light & Power Company, Ltd. (30 May 1882)	£88,928	£70,218	£168,518 Never quoted in *IMM*.	£30,473	£79,590	£11,000 [1]	Second (and final) liquidation, 1894.
2.	London & Provincial Electric Lighting & Power Generating Co., Ltd. (January/February 1882)	£85,000	£85,000	£125,000 Never quoted in *IMM*.	£30,000	£40,000	Nil	Compulsorily wound up, 3 November 1883.
3.	British Electric Light Company, Ltd. (4 October 1878)	£72,410	£37,800	£72,410 Never quoted in *IMM*.	None noted. [2]	None noted. [2]	£6,922 [3]	Foreclosure by debenture holders, 1895. [4]
4.	Pilson, Joel & General Electric Company, Ltd. (January/February 1882)	£61,208	£48,966	£121,208 Peak market value, £82,087, Oct. 1882	£28,887 [5]	£60,000	£4,306 [6]	Voluntary winding-up resolution, 14 December 1888.
Page Totals: 4 companies		£307,546	241,984	£487,136	£89,360	£179,590	£22,228	Nil value.

1. No dividends; cash from first liquidation and re-structuring, May 1887. 2. A payment may have been missed by *Burdett's*, since the company had sold rights to the Gramme dynamo to London & Provincial Electric (see entry #2 above) before the end of 1882. British Electric Light must have paid something for the rights which it in turn sold on. 3. Dividends only; paid in 1880-81. 4. Debentures were issued in 1888 to satisfy creditors, thereby (temporarily) avoiding liquidation. 5. Total includes £13,887 paid to patent holders in exchange for the cancellation or surrender of their fully-paid ordinary shares. 6. Dividends, £1,233; liquidation payout, £3,073, implied by last quote, made just before voluntary winding up.

Table 1C [con't.] Summary of the Financial Experience of the "The Rest"								
		1.	1a.	2.	3.	3a.	4.	5.
Company (Date of creation)		Total cash raised by ordinary share issue before end-June 1914	Of which: cash raised in 1882	Total nominal value of ordinary shares issued before end-June 1914	Cash paid for patents	Nominal value of ordinary shares issued for patents (fully paid unless otherwise noted)	Total cumulated cash pay-outs received by holders of ordinary shares through end-June 1914	Date of termination or value at end-June 1914
5.	Railway & Electric Appliances Co., Ltd. (31 March 1882)	£57,358	£57,358	£135,858 Never quoted in *IMM*.	£16,500 [1]	£78,500 [1]	Nil	In liquidation in 1887.
6.	J.B. Rogers Electric Light & Power Co., Ltd. (January/February 1882)	£46,286	£46,286	£96,286 Never quoted in *IMM*.	£6,000	£50,000 [2]	Nil	Voluntary liquidation completed by early 1885.
7.	Electric Lighting Contract & Maintenance Co., Ltd. (January/February 1882)	£39,918	£39,918	£39,918 Never quoted in *IMM.*	None	None	£20,000 [3]	Voluntary liquidation conducted by two former directors in 1883.
8.	Duplex Electric Light, Power & Storage Co., Ltd. (January/February 1882)	£35,000	£35,000	£35,000 Never quoted in *IMM.*	None [4]	None [4]	£18,130 [5]	Wound up and re-organized, 14 July 1883. [5]
Page Totals: 4 companies		£178,562	£178,562	£307,062	£22,500	£128,500	£38,130	Nil value.

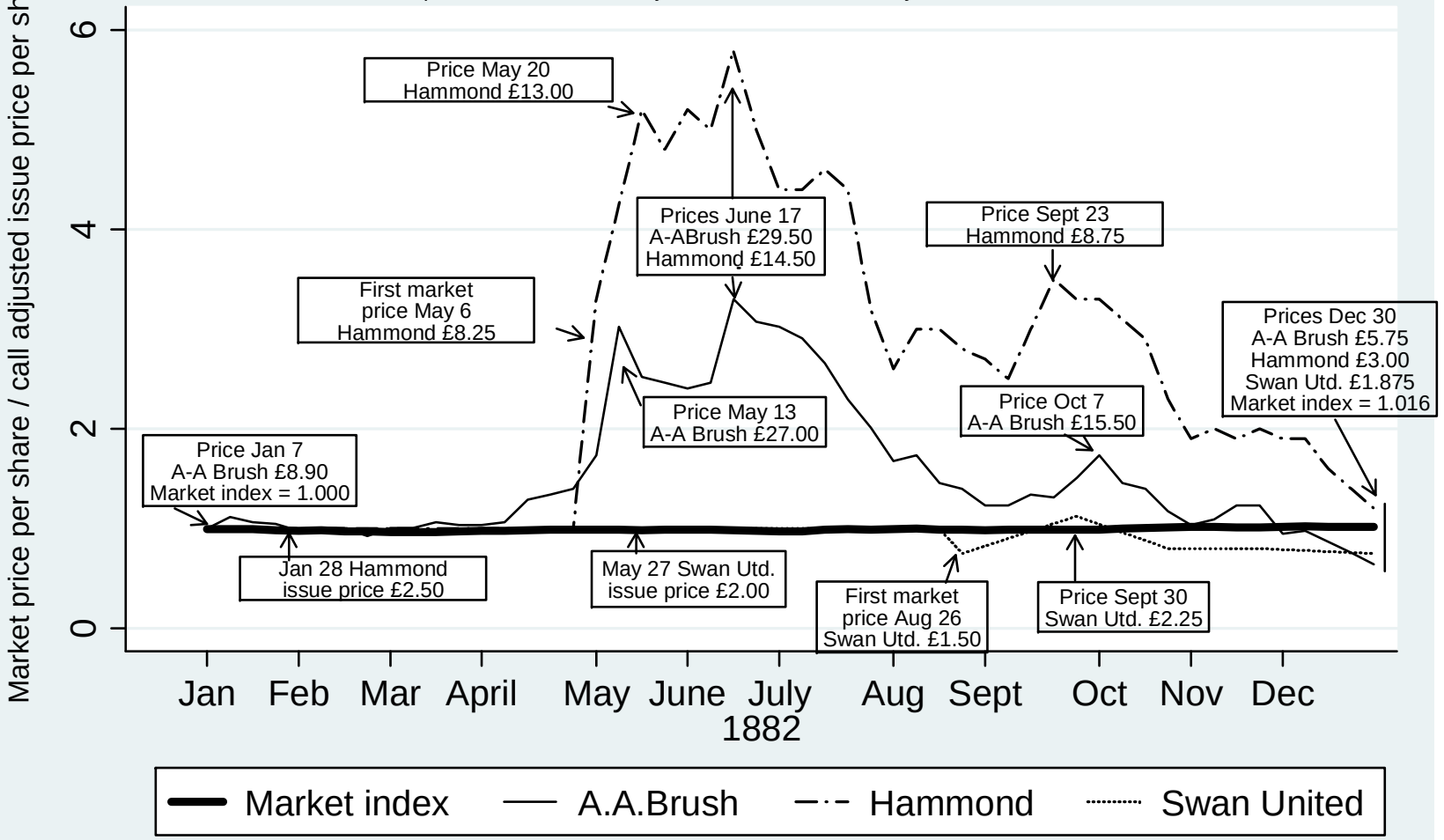
1. Paid to Maxim-Weston Electric. 2. £34,000 in deferred debentures was also paid. No interest was ever paid on them. 3. Some 50% of the cash raised was assumed returned in the early voluntary liquidation conducted by former directors. 4. There was a promise of royalties, but no cash or shares were reported paid. 5. Of which: dividends £4,375; liquidation pay-out, £13,755, paid by Economic Electric Light Company to acquire assets and resume operations. The successor company entered voluntary liquidation in 1884.

Table 1C [con't.] Summary of the Financial Experience of "The Rest"								
		1.	1a.	2.	3.	3a.	4.	5.
Company (Date of creation)		Total cash raised by ordinary share issue before end-June 1914	Of which: cash raised in 1882	Total nominal value of ordinary shares issued before end-June 1914	Cash paid for patents	Nominal value of ordinary shares issued for patents (fully paid unless otherwise noted)	Total cumulated cash pay-outs received by holders of ordinary shares through end-June 1914	Date of termination or value at end-June 1914
9.	Electric Carbon Storage & Apparatus Company of Scotland, Ltd. (January/February 1882)	£30,000	£30,000	£45,000 Never quoted in *IMM*.	None [1]	None [1]	£9,000 [2]	Liquidated 6 September 1883 in Leith, Scotland.
10.	Phoenix Electric Light & Power Company (January/February 1882)	£21,250	£21,250	£21,250 Never quoted in *IMM*.	None.	None.	Nil.	Notice of winding up, 1883.
11.	Electric "Sun" Lamp & Power Company. (January/February 1882)	£20,226	£20,226	£70,226 Never quoted in *IMM*	Unspecified [3]	£50,000 [4]	Nil [5]	Liquidated in 1884.
12.	W.T. Henley Electric Light & Power Company (2 June 1882)	£20,000	£20,000	£100,000 Never quoted in *IMM*	£20,000	£30,000	Nil	Liquidated around 1884. [6]
Page Totals: 4 companies		£91,476	£91,476	£236,476	£20,000	£80,000	£9,000	Nil value.
Grand total: 12 companies		£577,584	£512,022	£1,030,674	£131,860	£388,090	£69,358	Nil value. [7]

1. £10,000 cash was paid for freehold property, plus £15,000 (nominal) in ordinary shares issued half paid-up. 2. £9,000 was the assumed value of freehold property upon liquidation of the company. 3. An unspecified amount of cash (clearly less than £20,226) was paid. 4. Deferred ordinary shares. 5. A debit balance on profit and loss account stood at £6,083 at the end of December 1883. 6. Last recorded in *Burdett's* in 1884. The company appears to have been quietly absorbed by W.T. Henley Telegraph Works, a long-established company and a major shareholder from whom patent rights had been purchased. 7. None of the 12 companies survived to 1914.

Figure 1. Weekly share prices (call adjusted) of quoted British electrical companies 1882

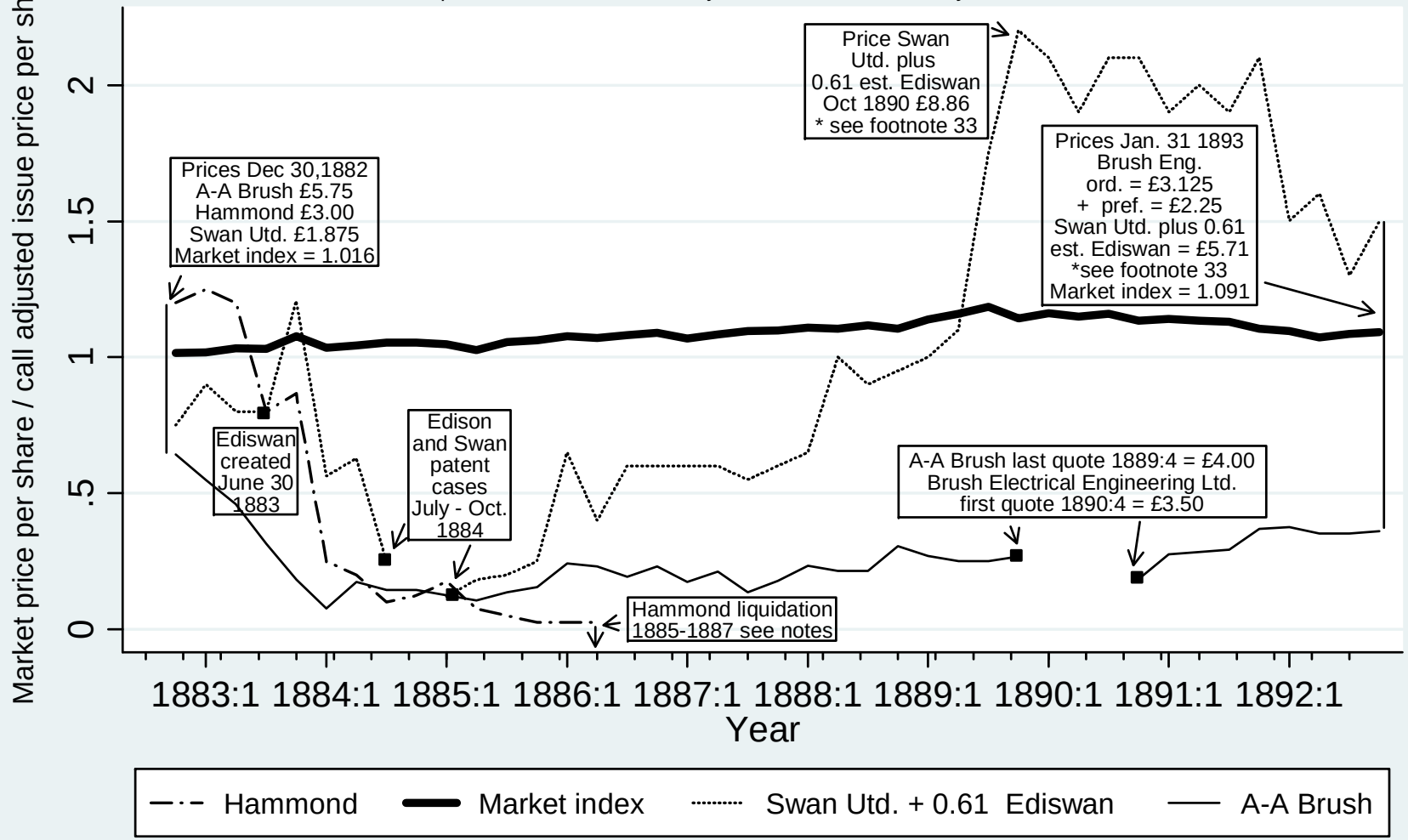
Initial price in 1882 = 1.00. Adjustment for calls occurs by increase in denominator.



Initial amount is issue price until market quotes become available
A-A Brush shares were initially £4.00 paid on £10.00 shares, with additional calls to occur in 1883, as announced December 1, 1882.
Hammond shares were issued with £2.50 paid-up on £5.00 shares. Swan United shares were issued with £2.00 paid-up on £5.00 shares; £0.50 being called Oct 1 1882.

Figure 2. Quarterly share prices (call adjusted) of selected quoted British electrical companies 1883-1892

Initial share quotation in 1882 = 1.00. Adjustment for calls occurs by increase in denominator.



Hammond in liquidation 1885. Last quote £0.125 April 1886. Liquidation completed 1887. Shareholders received £0.15 per share, £5 paid up
There were no quotations for Swan United during the period of patent litigation (see footnote 33). Post-merger prices track remaining business of Swan United plus 0.61 shares of Edison and Swan United.
A-A Brush reconstituted as Brush Electrical Engineering Ltd. (BEE) giving gap 1889-1890.