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Shadow factories in Britain and Germany: Towards an international model of war economies in the 1930s and the Second World War.

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30 March 2010

1 International similarities between war economies

Historians of the Second World War often try to identify unique features of a particular national war economy which help to explain the above- or below-average economic performance of that country in an international perspective. The institutional and organisational context may be highly significant: ideological or political factors may act either to constrain or facilitate industrial production and technological innovation, whilst military, business and scientific élites exercise varying degrees of power and influence within a state. The inadequacies in Britain's preparations for war in the 1930s are frequently explained by reference to the disadvantages suffered by democracies in comparison to dictatorships: Germany was able to create a *Wehrwirtschaft* – a war economy during peacetime – but British rearmament had to keep step with slowly-evolving public opinion.

At the beginning of the Second World War, however, it is often argued that the comparatively low productivity in German armament production was caused by the dominance of military authorities over the civilian administration when it came to the procurement of armament goods. As Richard Overy has written:

> This was done with almost no co-operation between the three armed services, which led to endless duplication of productive effort and the jealous guardianship of resources and factory space. It was also done with virtually no attention to the wider problems of the industrial economy or with rational production methods in mind.[1]

[1] Overy, R. J. (1994). *War and Economy in the Third Reich*. Oxford: Clarendon Press, p. 347.

In the US, too, civilian mobilization agencies were overruled by the armed forces. Cullen and Fishback suggest that: "The military decided where contracts were allocated with little inference from the War Production Board. Economic problems in counties received virtually no systematic consideration in distributing funds [...]."[2] But, in contrast to the German case, the dominance of military authorities in the American war economy appeared to increase rather than slow down the velocity of armament production. Can both interpretations be valid at the same time or is the role of the military in procurement misunderstood in at least one of the cases? More generally, is the dominance of military authorities in procurement a particular feature of just a few, national economies in the Second World War or is it rather a characteristic that most warring states had in common?

By drawing on international comparisons for the 1930s and 1940s, this essay intends to demonstrate how the rearmament preparations and the war economies of the combatants were generally far more similar than many studies suggest. The extent of the similarities might even imply the existence of an international model of a modern war economy. A model constructed around the commonly-held characteristics of the different war economies could not, of course, claim to be all-embracing. On the contrary, if such a model were established the remaining differences - such as the mass employment of forced labour in Germany - would be thrown into stark relief. Overall, the purposes of broad historical understanding as well as the interpretation of specific phenomena might then be better served.

First of all, there are many similarities at the macroeconomic level. In this respect, Harrison's study of Second World War economics offers a comprehensive framework for discussion.[3] Many countries witnessed a dramatic rise of military spending on the eve of and during the Second World War; this led to a sharp decline in private consumption (usually enforced by price controls and rationing). Expenditure was often financed by money creation and also, on the part of the Axis powers, by exploiting the resources of occupied countries and appropriating the assets of minorities such as the Jews. This rise in military spending triggered a rapid and unexpected increase in armament production which, in more than one country, was christened an "armament miracle" or a "production miracle". With the exception of the US, the combatants' war economies depended heavily on the import of raw materials and vital

[2] Cullen, J. and Fishback, P. (2008). *Does Large-Scale Military Spending Stimulate Local Economies? The Implications of WWII Spending for Local Economic Activity, 1939-1958.* Unpublished paper, p. 6.
[3] See Harrison, M. (ed.) (1998). *The Economics of World War II: Six great powers in international comparison*. Cambridge: University Press.

armament goods. Given the vulnerability of foreign trade during wartime, the availability of domestic strategic resources was decisive for the outcome of the war. It is possible to argue that a country's participation in World War II fostered R&D, human capital formation and investment in new machinery and technology and thereby led to modernization and faster growth in the postwar period.[4] However, one analysis of the UK suggests that the long-run impact of the war on national wealth was negative.[5]

More striking than any similarities at the macroeconomic level, is what can be said about the relationship between industry and government in national economies. For, notwithstanding the obvious ideological differences between states, many similarities clearly existed at the level of implementing and operationalising armament policies. This implies that the Allied democracies used, by and large, the same means as the Axis dictatorships to foster armament production. All governments procuring weapons and other goods from private firms had to deal with the trade-off between increasing efficiency when using fixed-price contracts and decreasing expenses and transaction costs when deploying cost-plus contracts.[6] Given the overheated boom of the war economies most governments had to rely on bilateral negotiations with single armament manufacturers instead of using competitive bidding to award armament contracts. Governments had to finance many additional armament plants because private firms were not willing to take the risk of investing in what they assumed would become excess capacity once the war had ended and, consequently, of little value. Geo-strategic considerations often determined the location of new plants and led to a geographical re-allocation of labour. In addition to creating new facilities, considerable adjustment costs were incurred in the short run by converting plants producing consumption goods to armament plants. To replace male workers drafted into the armed services, governments tried to increase the industrial employment of women: while US publicity campaigns idealised workers such as 'Rosie the Riveter', the female labour force in the Third Reich also became increasingly important even though Nazi propaganda exalted women's domestic roles.

[4] See, for example, for the German discussion Abelshauser, W. (1999). Kriegswirtschaft und Wirtschaftswunder. Deutschlands wirtschaftliche Mobilisierung für den Zweiten Weltkrieg und die Folgen für die Nachkriegszeit. *Vierteljahrshefte für Zeitgeschichte* 47: 503-538; Buchheim, Ch. (2001). Die Wirtschaftsentwicklung im Dritten Reich - mehr Desaster als Wunder. Eine Erwiderung auf Werner Abelshauser. *Vierteljahrshefte für Zeitgeschichte* 49: pp. 653-664.

[5] Stephen Broadberry & Peter Howlett (1998) *The United Kingdom: 'Victory at all costs'* Cambridge: CUP, p. 72.

[6] See, for example, Streb, J. (2003). Can Politicians Speed Up Long-Term Technological Change? Some Insights from a Comparison of the German and US-American Synthetic Rubber Programs Before, During and After World War II. *Essays in Economic and Business History* 21: pp. 33-49, Streb, J. (2009). Negotiating Contract Type and Contract Clauses in the German Construction Industry during the Third Reich. *RAND Journal of Economics* 40: pp. 364-379.

Finally, there are several similarities at the microeconomic level of armament firms. Of particular interest are studies that have looked at how production was organised. Analyzing the data of 22 different aircraft types produced by American industry during World War II, Alchian was the first to observe that the direct amount of labour required for producing a unit of a special aircraft type regularly declined when the total output of this type was expanded.[7] It appears that worker efficiency increases the more frequently a special task is repeated. Reviewing the wartime output of B-17s from Boeing's Plant No. 2 in Seattle, Washington, Mishina noticed that the management learned in the course of the manufacturing process how to increase worker productivity by improving the production system.[8] These improvements included the implementation of just-in-time production to clear the shop floor of stocks that were not necessary for current production runs, and the breakdown of the assembly process into finer sub-assemblies which increased the division of labour. Learning-by-doing by blue-collar and white-collar workers occurred in all kinds of industries, but the resulting increase in labour productivity was especially high when workers were given rather complex tasks - as was the case in the aircraft industry. Budrass, Scherner and Streb have reached the same conclusion for the German aircraft industry during the Second World War.[9] In addition, this new research confirms that there was a dramatic increase in inter-firm division of labour in the German aircraft industry. This allowed both the final-assembly manufacturer and the component suppliers to concentrate on their respective core competences and, thereby, economies of scale to be realised. Tetsuji Okazaki also claims that outsourcing production by expanding supplier networks was the most important reason for the "miraculous" acceleration of aircraft production in the Japanese war economy.[10]

The international similarities between both the armament policies of governments and the microeconomic changes within firms suggest that it might be misleading to make a sharp distinction between the "market-oriented" war economies of the Western Allies and the "centrally-planned" war economies of Russia and the Axis powers. Instead, perhaps it should

[7] See Alchian, A. (1963). Reliability of Progress Curves in Airframe Production. *Econometrica*, 31:pp. 679-693.

[8] See Mishina, K. (1999). Learning by New Experiences: Revisiting the Flying Fortress Learning Curve. In N. R. Lamoreaux, D. M. G. Raff and P. Temin (eds.) *Learning by Doing in Markets, Firms and Countries*, Chicago: University Press: pp. 145-184. International evidence for continuous cost reductions in the production of various armament goods is presented in Harrison, M. (1996). *Accounting for War: Soviet Production, Employment, and the Defence Burden, 1940-1945*, Cambridge: University Press, pp. 225, 231.

[9] See Budrass, L., Scherner, J. and Streb, J. (2010). Fixed-price Contracts, Learning and Outsourcing: Explaining the Continuous Growth of Output and Labour Productivity in the German Aircraft Industry during World War II. *Economic History Review*, 63: pp. 107-136.

[10] See Okazaki, T. (2008). *Supplier Networks and Aircraft Production in Wartime Japan*. Unpublished paper.

be assumed that the requirements of fighting a material-intensive, global conflict led all warring countries to build up the same type of modern war economy, despite their insurmountable ideological differences. Rather than examining the special features of a single war economy, this essay seeks to identify objectives and problems that were common to many national economies before and during the Second World War and to compare the similarities and differences of the respective national solutions to these problems. An important building block in the structure of war economies - somewhat neglected in the historical literature - were the "shadow factories" put up both in Germany and Britain from the mid-1930s. These factories were built and owned by the state but operated by private-sector firms; their purpose was not only to produce armaments and synthetic products in peacetime but also to lay down the capacity to satisfy a future and highly uncertain level of demand during wartime. The empirical analysis focuses on the history of the German factories - owned by the public-holding company *Verwertgesellschaft für Montanindustrie GmbH* (MONTAN)[11] - and on those constructed in the city of Coventry – the key centre for the British scheme.

Both Britain and Germany were driven to establish shadow factories by the same political objective - the need to prepare for upcoming war by creating additional capacity for mass-produced armament goods which, it was clear from the beginning, could not be profitably disposed of during peacetime. But, in seeking to develop this capacity, both governments encountered major problems. These were the risk-aversion of private armament manufacturers, the necessity to hide or disguise in some fashion the building-up of new armament plants from domestic and foreign observers, the choice of locations which were both safe, or considered relatively so, from a strategic point of view and feasible from an economic perspective, the opposition of the local population against the new armament plants, and, last but not least, the utilization of the technological know-how of the established armament and engineering firms. The following sections analyse how Germany and Britain attempted to solve these various problems and the essay concludes by pointing to possible directions for future research.

2 Shadow Plants in Germany and Britain

2.1 Risk-averse armament manufacturers

By the middle of the 1930s the Nazi government planned and promoted a considerable increase in investments by private firms in the armament industries and in autarky – the drive

[11] A complete list of these German "shadow factories" can be found in Hopmann, B. (1996). *Von der MONTAN zur Industrieverwaltungsgesellschaft (IVG) 1916-1951*. Stuttgart: Franz Steiner, pp. 79-80.

to achieve self-sufficiency in vital, strategically important raw materials by developing industrial capacity, especially in manufacturing synthetic products. Scherner shows that instead of using coercive authority or violence to enforce investment schemes the government, in general, tried to attain the voluntary cooperation of firms by offering a set of different investment contracts. Private investors could then choose the contract type that suited their own economic objectives best.[12] Firms did not want to risk investing in unprofitable, excess capacity and therefore based their choice of contract primarily on their expectations about the return on the respective investment. Figure 1 visualizes this relationship between expectations and contract choice.

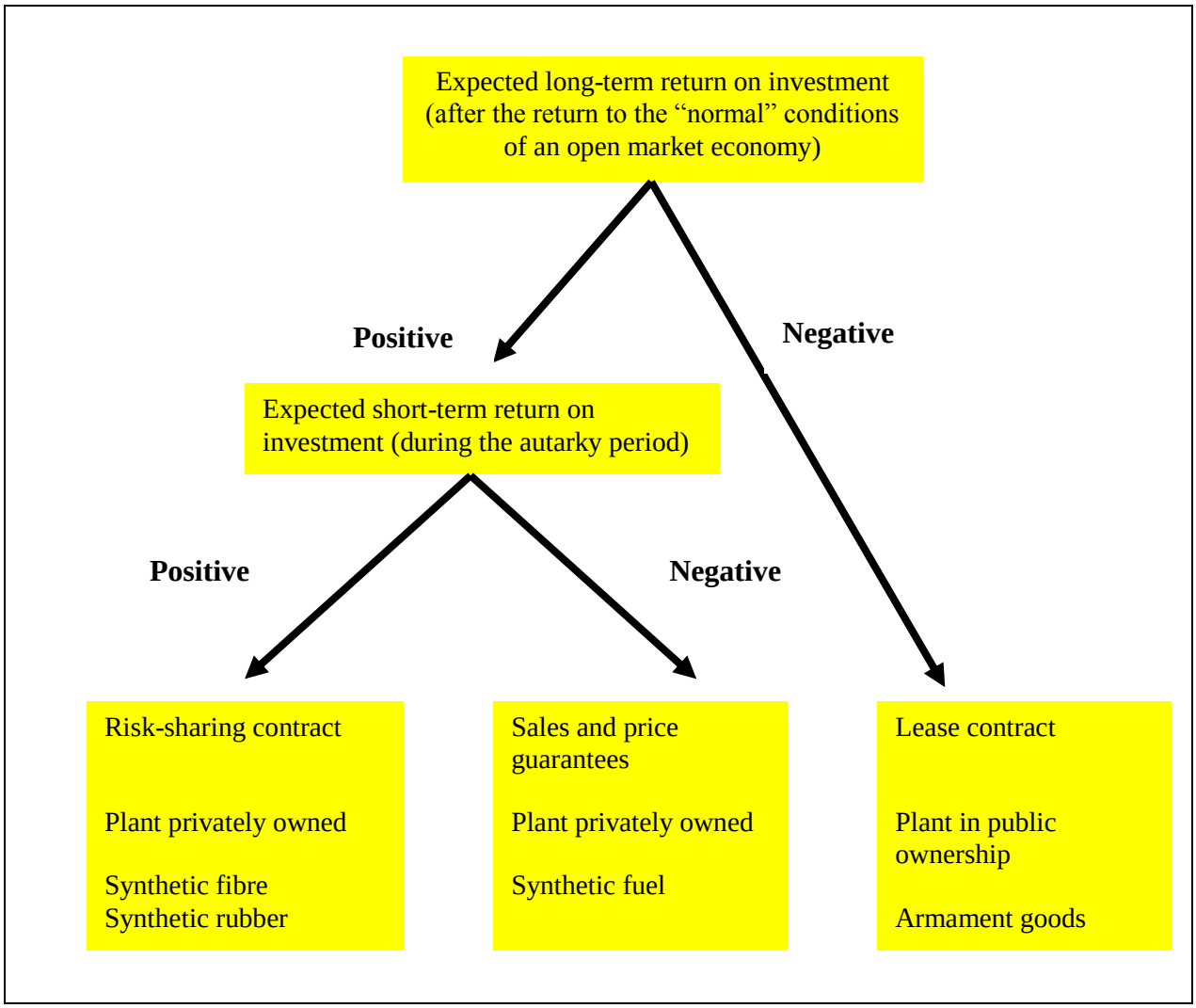
Scherner distinguishes between short-run and long-run expectations. In the short run it was assumed that the Nazis would stick to policies of autarky and armament by means of price controls, rationing, re-allocation of labour and raw materials, protectionism and foreign-exchange control. German firms believed that this period of extensive interventionism was only a transitional one. In the long run, they expected a return to a functioning and internationally-open market economy.[13] When firms expected that a particular investment project promoted by the government would be profitable, regardless of the timescale, they were clearly interested in owning new plant and were, therefore, willing to finance it completely themselves. Alternatively, firms could choose a risk-sharing contract by which the government committed itself to finance a part of the investment project. In return, firms had to grant the government some control rights and co-determination. Many of the plants for the German synthetic fibre and synthetic rubber industry were constructed using these risk-sharing contracts.

When firms believed in the long-term profitability of an investment project but expected short-run losses, they could opt for a special type of investment contract (*Wirtschaftlichkeitsgarantievertrag*). Under these terms, the government promised to buy an annually-given volume of goods produced in the new plant, at a fixed, minimum price, for a given period (such as ten years). The firms still had to finance plant construction themselves, but bore no risk in the period covered by the contract because the fixed minimum price also included a "reasonable" return on investment. Once again, in compensation for carrying all

[12] See Scherner, J. (2008). Investment Contracts between State Agencies and Industry in the Third Reich. In C. Buchheim (ed.). *German Industry in the Nazi Period*. Stuttgart: Franz Steiner: pp. 117-131.
[13] For many historical examples that confirm this view see Scherner, J. (2008). *Die Logik der Industriepolitik im Dritten Reich. Die Investitionen in die Autarkie- und Rüstungsindustrie und ihre staatliche Förderung*. Stuttgart: Franz Steiner Verlag.

the investment risk, the government exercised control rights and co-determination. This type of investment contract was used, for example, in the synthetic fuel industry.

Figure 1 The optimal choice of investment contract in the Third Reich



When firms judged the project to be an unprofitable investment both in the short and long run they were, understandably, not at all interested in private ownership. In this case, the government financed construction of the additional production capacity completely out of public funds and then, as the owner, leased the new plant to an existing private firm for a given period. The cost of the lease to the firm was set as a given share of the actual profits realized by selling the products made in the plant. Since, under such a leasing contract, the government guaranteed product prices - which usually covered all variable production costs - the firms bore neither am investment nor an operational risk.

In Nazi Germany, such lease contracts were especially used for establishing the so-called army-owned factories (*Heereseigene Betriebe*), including the armament industry's shadow factories. In 1944, there were 101 army-owned factories in operation, producing explosives, weapons, ammunition or tanks, with a total sum of 211,800 employees.[14] The public company MONTAN owned the factory premises and also financed the building-up of the new facilities with the help of army funds. Reputable manufacturers of armament goods like *Deutsche Waffen- und Munitionsfabriken AG*, *Rheinmetall Borsig* or *I.G. Farben* were charged with supervising and accomplishing the investment projects. After a factory was completed, MONTAN leased it to a newly-founded subsidiary of the armament manufacturer which had been responsible for the construction process. This subsidiary operated the factory and paid between an half and two-thirds of its operating profits as rent to MONTAN.[15] Consequently, with the help of such lease contracts, MONTAN could use the technological know-how and experience of the German armament manufacturers who were unwilling to invest in additional production capacity either by constructing the shadow factories before the war or for operating them during it. Scherner shows that the investment in the army-owned shadow factories (and the so-called army-owned machines also leased to private firms) was not a quantité negligable but came to about 30 percent of total German armament investment (3393 million Reichsmarks) between 1934 and 1939.[16]

This type of "state-owned" armament or autarky factory was on no account a unique feature of the Nazi war economy but can be found in the war economies of the Allies too. American synthetic rubber production was also regulated by lease- and plant-operating agreements.[17] Under lease contracts, private American tyre manufacturers agreed to set up new plants. The US government's *Defense Plant Corporation* financed this investment programme and was therefore the owner of the plants; on completion, they were leased to the tyre manufacturers

[14] See Hopmann, B. (1996). *Von der MONTAN zur Industrieverwaltungsgesellschaft (IVG) 1916-1951*. Stuttgart: Franz Steiner, pp. 111, 117.
[15] See Hopmann, B. (1996). *Von der MONTAN zur Industrieverwaltungsgesellschaft (IVG) 1916-1951*. Stuttgart: Franz Steiner, pp. 71-76
[16] See Scherner, J. (2010). Nazi Germany's Preparation for War: Evidence from Revised Industrial Investment Series. Forthcoming in *European Economic History Review*.
[17] See Appendix XXIII "Agreement of Lease" and Appendix XXVII "Typical Copolymer Plant Operating Agreement". In: The Government's Rubber Projects, Vol. 2. *A History of the U.S. Government's Natural and Synthetic Rubber Programs 1941-1955.* Originally prepared 1948 in the Division of Information Reconstruction Finance Cooperation, under the direction and supervision of W. P. Tidwell by B. J. O'Callaghan. 1955 revised and brought up-to-date under the supervision of B. H. Wimer. These appendices were only added to the original manuscript and are kept in the National Archives Washington/DC, Entry 26 „Administrative Histories of the RFC's Wartime Programs", Location 570, 65:33:7 / Box 16.

for the symbolic sum of one dollar per year. The plant-operating agreement dealt with the actual synthetic rubber production and was arranged as a cost-plus contract. The private leaseholders produced the quantity of synthetic rubber that was commissioned by the government's *Rubber Reserve Company* and received, in return, prices that covered all their production costs.[18] As in the German case, the American firms bore no risks. There was one, main difference between the German army-owned armament factories and the US government-owned synthetic rubber plants: the latter were not planned and built up as shadow factories before the war but were rapidly established following the Japanese attack at Pearl Harbor on December 7th, 1941, and the subsequent invasion of south-east Asia's natural rubber plantations. Fully in line with the German case, however, British armament plants were also established as shadow factories well before the actual outbreak of war.

The institutional solution for establishing shadow factories in Britain was the same as in Germany. As Lord Weir, the industrialist who is credited as the progenitor of the scheme, told Baldwin in 1935, he was against doing anything that would turn industry upside down but felt that, "we must quietly but very rapidly find an effective British compromise solution as opposed to merely copying the centralised dictator system."[19] This would certainly have appealed to the Conservative-dominated National Government; the shadow scheme was a way for the state to pay and own munitions factories that would, it was believed, be built and operated more efficiently by the private sector. One historian, David Edgerton, even suggests that the scheme demonstrated a straightforward bias in favour of private enterprise and that the government believed that the employers concerned would find it easier to shut the factories when demand for armaments fell.[20]

Concentrating on the development of a single war economy, Edgerton interprets state-industry relations in shadow production simply in terms of the ideological complexion of the British government – a traditional preference for entrepreneurship and private enterprise. But these developments should not be seen in isolation; only by locating them in a wider, international

[18] The different ways government procurement contracts were arranged explains why the German synthetic rubber fabricators reduced their production costs through increases in efficiency considerably more than the American producers whose cost savings can be attributed primarily to a technological change in the upstream butadiene production. A profit increase in Germany was possible under the actual conditions of a fixed price contract primarily through cost reductions. In the USA, increased profits were possible in the framework of cost-plus contracts through production increases. See Streb, J. (2003). Can Politicians Speed Up Long-Term Technological Change? Some Insights from a Comparison of the German and US-American Synthetic Rubber Programs Before, During and After World War II. *Essays in Economic and Business History* 21: pp. 33-49.
[19] Quoted in, Robert Paul Shay (1977). *British Rearmament in the Thirties: Politics and Profits.* Princeton, p. 94.
[20] David Edgerton (1991). *England and the Aeroplane: an Essay on a Militant and Technological Nation*. Basingstoke, p. 75.

context of armaments production can they be properly explained. If the "lease contract" was introduced by Britain as the means to establish shadow factories, why was there a parallel and simultaneous development of this stratagem in Nazi Germany? Starting with the political objective to establish additional armament plants - common to many European economies in the 1930s - it would seem that the introduction of the "lease contract" was an internationally-efficient solution for the problem that private firms were not willing to take the risk of investing in excess capacity.

What haunted the British political élite was the deeply traumatic experience of fighting between 1914 and 1918 what proved to be the first modern, industrial war . The vain hopes that business could be carried on as usual, and that the free market would simply supply what war goods were required, led in 1916 to the so-called 'shell scandal' of a shortage of munitions and ensuing political upheaval. Rather than wait for hostilities to break out once more before mobilising society's resources, civilian expertise was, from the mid-1930s, increasingly incorporated into the planning and preparations for war. The question of how to reorganise armaments procurement was the catalyst for bringing back Weir, one of the leading industrialist-technocrats of the age, to the centre of decision-making.[21]

The shadow scheme was designed to take account of the existing, severe capacity-constraints in the engineering sector of the British economy. The alternatives to using the private-sector – a state owned and operated armaments industry - would certainly have turned industry upside down. It would have required government to take powers to direct and control skilled labour and executive personnel; many feared that measures on such a scale would put the financial and economic stability of the country at risk.[22] At the very least, it would have caused enormous resentment among employers. The scheme also provided a way to switch production, rapidly and comprehensively at the outbreak of war, away from civilian goods.

Reflecting on Churchill's criticisms in 1935 concerning the enfeebled condition of Britain's defences, Weir posed the key question: "Are doing all we ought to anticipate by proper planning and arrangement the grave delays which were the feature of our almost fatal

[21] Churchill Archives Centre, Cambridge, UK, Lord Weir Papers (hereafter CAC, Weir), Weir 19/1, letter, 20 May 1935, from Lord Londonderry (Secretary of State for Air) to Weir. Londonderry, referring to the great problems facing them, wrote: "Your name carries such weight and inspires such confidence in the country…".
[22] CAC, 19/2, note by Weir, 10 June 1936, "Acceleration of defence measures". This note was drawn up after consulting Sir Thomas Inskip, the newly-appointed Minister for Co-ordination of Defence, and was circulated among ministries.

unpreparedness in 1914?" Weir declared himself to be fully in sympathy with Churchill in believing that little or nothing was being done.[23] Thus Weir set himself the objective of pursuing the various alternative ways of increasing peacetime production and at the same time perfecting the arrangements for preparing for war.[24] To Churchill, and doubtless to many others, these preparations were far from obvious. He asked Weir: "Are you quite sure you are right in lending all your reputation to keeping this country in a state of comfortable peace routine?".[25] But Viscount Swinton, the Secretary of State for Air, told the Committee of Imperial Defence that by erecting factories and allowing the shadow firms to gain experience, the scheme was turning this 'war potential' into an actual asset. The firms were engaged in estimating how far their civil plant would be useful for war work and the extent to which it would have to be supplemented by new machinery.[26] As the international crisis developed, the ideological battle intensified. Reviewing the position in the wake of the *Anschluss*, Weir believed that Britain had to avoid any admission that Germany's supposed super-efficiency in armament strength, "can only be secured by dictatorship rule. A democracy ought to be able to apply itself to these problems."[27]

Rearmament for Britain in the 1930s involved making decisions about where and how to allocate resources after weighing up a bewilderingly array of geo-strategic issues, risk factors and opportunity costs. In March 1934, Baldwin promised the House of Commons that Britain would not accept in air power a position of inferiority to any country within striking distance of British shores. The deterrent of counter-bombing – specifically targeted against Germany - was considered the most likely guarantee of British security. The Air Ministry, therefore, drew up programmes that laid stress not only on the production of heavy bombers but also on establishing deep reserves. The combined efforts of the Ministry and the aircraft industry to reorganise the manufacturing base were supported by the Treasury which prioritised these efforts, allowing the necessary industrial resources to be secured.[28] But, there were serious deficiencies and weaknesses in the performance of the British aircraft industry.[29] Military strategists were especially concerned at the apparent disparities between the British and

[23] Weir, 19/12, minute, 22 Aug.1935, Weir to P.Cunliffe-Lister, (created Viscount Swinton), Secretary of State for Air. In correspondence with Churchill, Cunliffe-Lister described Weir as "an absolute God-send".
[24] Weir 19/2, minute, 30 Jan.1936, Weir to Secretary of State.
[25] Weir 19/12, letter, 6 May 1936, Churchill to Weir.
[26] Weir, 19/2, minutes of C.I.D. meeting, 19 Nov.1936.
[27] Weir, 19/18, note for talk with Secretary of State on 15 March 1938.
[28] See Parker, R. A. C. (1989). *Struggle for Survival: the History of the Second World War.* OUP, p. 50; Peden, G. C. (1979). *British Rearmament and the Treasury: 1932-1930.* Edinburgh, p.160; Hancock, W. K. and Gowing, m. M. (1949). *British War Economy. History of the Second World War: UK Civil Series.* London, p. 66.
[29] Glyn Stone, 'Rearmament, War and the Bristol Aeroplane Company, 1935-1945' in Charles Harvey and John Press (eds.), *Studies in the Business History of Bristol*, Bristol: Bristol Academic Press, 1988, pp. 187-212.

German aircraft industries. In 1935, the General Staff in the War Office noted that, "The political and economic organisation of the German state is more favourable than our own to the adaption by industry to the production of war equipment of every variety".[30]

British plans were based on an estimate, dating from 1931, that the requirements for aircraft and aero engines during the first year of a future war would be procured by adding five large motor car firms to the existing aircraft constructors.[31] However, very quickly after taking up his new role of adviser in May 1935, Weir could see that even the peacetime demand for aero engines was likely to outstrip the means of supply. He told the Air Ministry, "The best expansion channel for this, if needed, should come from the automobile industry."[32] Indeed, by the start of 1936, the Ministry had begun to realize that the existing firms were not going to be able to meet the current rate of demand for aircraft – 4000 per year – and that a large order would have to be placed with one or more of the big motor firms. As Sir Christopher Bullock, the Permanent Secretary, noted, the War Office had started to draw on sources outside the normal armament industry and "they will have to rely on orders placed with a shadow supply organization for meeting an appreciable part of their deficiencies'".[33] Bullock could see no reason in principle – as long as there was no undue dislocation of normal industry - why aircraft should not be procured in the same way.

However, one factor above all others determined the character of the shadowing of armaments production in Britain: an adequate supply of the right kind of skilled and semi-skilled labour and management expertise. The greatest barrier to expanding the output of the aircraft constructors was a shortage of workers with appropriate skills. One of the firms experiencing these difficulties was Armstrong Siddeley in Coventry. According to one Air Ministry official, the firm was forced to engage in the disputatious practice of dilution – the substitution of semi-skilled for skilled workers – because "skilled labour is now practically unprocurable in Coventry".[34] Yet, paradoxically, the cause of this problem provided, at the same time, the means to solve it.

[30] National Archives, Kew, UK (hereafter NA), WO 32/3593, 'British and German Aircraft Industries', note for the Committee of Imperial Defence, 29 April 1935.
[31] CAC, Weir19/5, Defence Requirements Committee Paper, DC (M)(32) 138, April 1935, 'British and German Aircraft Industries'.
[32] CAC, Weir 19/2, Note on Rearmament, 11 June 1935. Weir believed that the aircraft industry was strong enough, at least, to construct airframes and that it wasn't necessary to encourage large shipbuilding firms, like Harland & Wolff, to enter the industry.
[33] CAC, Weir 19/1, letter, 7 Jan.1936, Bullock (Air Ministry) to Weir, enclosing a copy of a memo to the Secretary of State.
[34] Ibid., letter, 12 June 1935, B.E. Holloway (Air Ministry) to Weir.

This city had a long-established background as a national centre for armaments production; the manufacture of munitions and weapons before and during the First World War had already included the participation of the new motor vehicle industry in the production of aircraft. While the Great Depression had wiped out swathes of industry, resulting in the deskilling of many workers, the Birmingham-Coventry industrial axis escaped the worst elements of the crisis by combining technologically-advanced manufacturing with traditional metal-working interests. Buoyed up by the car industry, Coventry drew in waves of skilled and ambitious workers, engineers and entrepreneurs and became the fastest-growing city in Britain in the interwar years.

With aircraft production made a priority, the particular expertise in engineering and metal fabrication of the motor manufacturers, and the concentration of 'part-making' firms in the west Midlands, once again brought this region, and Coventry in particular, to prominence in the re-armament effort. These factors made it the obvious choice, in 1936, as the main base for the shadow factory scheme. Facilities to produce airframes, and particularly aero engines, could be located next to the existing factories of the motor companies, in order to utilise relevant skills and expertise of both managements and workers. Few, if any, alternative locations recommended themselves; the only realistic answer was to locate production in or close to those firms able to undertake the work. A study completed towards the end of the Second World War concluded that the dominant factor in the shadow factory plan was the attempt to benefit from the economy of large-scale organisation as distinct from that of large-scale production. In other words, the aim was to make the best use of the exceptionally able, higher management that was to be found in Coventry - an economy of entrepreneurship.[35] The willing co-operation of the existing aircraft industry was also required if the scheme was to operate effectively. A key manufacturer was the Bristol Aeroplane Company - responsible for building the Blenheim bomber.[36]

As the scheme progressed, earnings in the Midlands shadow factories came to be among the highest in the engineering industry. The Air Ministry felt vulnerable over the difficulties in controlling the distortions in the labour market that this caused, such as the competitive bidding up of wages as managements were released from the constraints that would have operated normally. This risked alienating other employers who did not enjoy such a privileged

[35] A. Shenfield & P. Sargant Florence (1944-45), 'The Economies and Diseconomies of Industrial Concentration: the Wartime Experience of Coventry', *Review of Economic Studies*, Vol. 12 (1) pt. 2, 79-99.
[36] G. Stone, 'Rearmament', p.202.

position. However, the scheme could also take advantage of the stance taken by the Midlands engineering firms on dilution which, in spite of the concerns of the trades unions, was not automatically considered an abnormal practice in the sector. Once war broke out, dilution was introduced rapidly on a large scale.[37]

The layout and plant of the shadow factories were designed for quantity production rather than experimental or development work. The most important were the factories that were to produce aero engines; the No.1 group (as it came to be called) was laid down in 1937-8 and the No.2 group in 1939-40. Swinton initiated this aspect of the scheme when, on 24 March 1936, he wrote to the motor manufacturers - Austin (based at Longbridge in Birmingham), Morris (based in Cowley, Oxford) and Coventry-based Daimler, Rover, Rootes (in the form of its subsidiary, Hillman Motors), and Standard. The Singer car company in Coventry was also contacted but was to play a very small part in the scheme.[38]

The first group of shadow engine factories were built alongside or very near to their parent works in Coventry. Most of the land was owned by the firms and might, in any case, have been used at some point for extensions to the car plants. Extraordinarily, only after construction had begun were terms discussed for the sale of the sites. The price the Air Ministry was prepared to pay was largely determined by valuing the opportunity costs for the companies concerned. As Hillman Motors had little room to expand for their own purposes at their Humber works (where the shadow factory was to be built) and because the Ministry wished to avoid alienating Rootes (the parent company), Swinton settled quickly to get the scheme underway as speedily as possible. The price the company wanted for the land was accepted.[39] In contrast, the Ministry believed that the price sought by Daimler was grossly inflated as their works occupied a large site (the Radford Estate) with plenty of space to expand. A price - £750 per acre instead of £1500 per acre originally sought - was not agreed until September 1937. The land was not legally conveyed until February 1938, by which the time the factory was in full production.[40]

[37] Inman, P. (1957). *Labour in the Munitions Industries. History of the Second World War: UK Civil Series.* London , pp 22-9, 320-1.
[38] NA, AIR 2/1738.
[39] NA, AIR 2/2325, minute by Swinton, 16 Aug. 1936.
[40] NA, AIR 2/2324, letter, 28 Sept.1937 from Daimler to Capt. Davies, Air Ministry; minute, 7 Feb. 1938, by Treasury Solicitor.

2.2 Vulnerability and Deception

German military planners had a strong interest in hiding the location and purpose of the shadow factories from the international public. Rearmament had begun in secret to hide violations of the Versailles Peace Treaty and to avoid antagonising neighbouring powers, and, in the early years of the Third Reich, the exact dimension of the rearmament programme was concealed. During the Second World War, the planners wanted to protect the shadow factories from air raids. To realize these objectives the Nazis used both an institutional and a geographical solution to hide the plants.

As indicated, shadow factories were not run by well-known armament firms but by newly-founded subsidiaries. These subsidiaries took the legal form of a limited liability company (*GmbH*) and so did not have to reveal the type and volume of their business in annual reports, as their parent companies were required to do under stock corporation law. To enhance the deception, existing German limited liability companies which produced civil goods, and which had innocuous-sounding names, were taken over by the parent company and then used to operate the shadow factory.

The second method used to hide the shadow factories was to locate them in rural areas - often within forests - far away from the western borders of Germany and, consequently, beyond the range of British bombers. The big disadvantage of this approach was that militarily-safe locations often lacked both the infrastructure for transporting raw materials and finished products and the workforce needed for the plants. As a result, the "optimal" location of a shadow plant was often a compromise between strategic and economic considerations. Overesch describes the careful and pains-taking process undertaken by Robert Bosch GmbH in weighing up the different factors in regard to the location of its shadow factory.[41]

In spring 1937, General Leeb, head of the *Heereswaffenamt*, asked Bosch (based in Stuttgart) to set up in northern Germany a new, army-owned factory needed to manufacture starter motors and dynamos for German tanks. The *Reichsstelle für Raumordnung* (Reich office for environmental planning) suggested building this new factory east of the river Weser and north of the geographical line between Kassel and Leipzig in order to put it out of reach of British or French bombers. Specifying this suggestion, in summer 1937, the *Reichsstelle für Raumordnung* presented a list of not less than sixteen different small and medium-sized

[41] See for the following paragraphs Overesch, M. (2008). *Bosch in Hildesheim 1937-1945*. Göttingen: Vandenhoeck & Ruprecht, pp. 40-95.

German towns judged suitable as a location for the new factory. In the following discussion Bosch stressed, besides the question of military vulnerability, several other, locational factors like the distance to major transport arteries or the availability of skilled workers. The firm was even concerned about the on-site supply of recreational facilities for its workforce. Finally, the town Hildesheim was selected as the location for the new shadow factory. Hildesheim was connected both to the Cologne-to-Berlin railway line and to the *Mittellandkanal* - the major German canal linking the Rhine and Elbe rivers. What is more, the town promised to provide housing for the workforce of the new firm.

To hide the new factory from the view of bomber pilots, it was erected not within the established town but within a near-by forest. According to the building plans no shed was made higher than the surrounding treetops. In addition, the sites of the various factory buildings were both scattered and staggered to diminish the impact of any bombing attacks not foiled by these means of deception. Another example of the strategy to locate shadow factories in rural areas, far away from Germany's western borders, were the eight shadow factories of Sprengchemie GmbH - the most important German manufacturer of gun powder during the war. These works were not concentrated in one area but were spread throughout Bavaria and Prussia.[42]

Although the isolated locations of German plants made them very difficult to spot and bomb from the air, one of the ironies of the pre-war years was that a great deal was known about some of them in Britain. In early 1935 Hitler repudiated the Versailles Treaty. Indeed, the frantic pace of rearmament became evident throughout the country and the growing strength of the Luftwaffe was even used as a propaganda weapon to cower potential enemies. But one British visitor, Roy Fedden, from the Bristol Aeroplane Company, was particularly well informed. Twice in 1937 he travelled to Germany and toured around different production facilities. His reports provided British intelligence services with the last accurate and comprehensive account before the outbreak of war of German capabilities and organisation in aircraft production.[43] That he was permitted such access is a reflection of how familial and close-knit the world of aviation was in the interwar years. Airframe design and engine technology was exchanged between British and German manufacturers such as Rolls-Royce,

[42] See Scherner, J. and Streb, J. (2008). Wissenstransfer, Lerneffekte oder Kapazitätsausbau? Die Ursachen des Wachstums der Arbeitsproduktivität in den Werken der Deutschen Sprengchemie GmbH, 1937 bis 1943. *Zeitschrift für Unternehmensgeschichte*, 53: pp. 100-122.
[43] Wesley K. Wark (1986), *The Ultimate Enemy: British Intelligence and Nazi Germany 1833-1939*. Oxford: OUP, pp. 65, 163.

Supermarine, Heinkel and Messerschmitt, until the early 1930s.[44] Not only did Fedden remain on friendly terms with German apprentices he had trained in the 1920s but, as one the leading aircraft engineers of his day, he was held in high respect by aircraft manufacturers everywhere.

Fedden's tour included a visit to Eisenach, where BMW had a motor car plant and a shadow aero engine plant; while the former occupied a site in the middle of the town, the latter was located a mile away on the town's outskirts. What amazed Fedden was that the shadow plant was invisible from anywhere in the vicinity: "Passing through the entrance gate you suddenly come upon the different buildings of the engine plant cunningly hidden amongst the pine trees on the sides of the hill". Equally impressive was the way air raid shelters were incorporated into buildings, and the general layout and organisation of the plant. Operations had commenced in early 1936 and the 1500 workers were engaged in switching production from the 'Hornet' - Pratt and Whitney air-cooled radial engines – to a more powerful German version.[45]

Whenever possible, new munitions plants in Britain were also built in locations away from parts of the country closest to continental Europe, even if no particular attempts were made to conceal them. Also considered, from 1935, were ways to induce the aircraft industry to transfer plants from London and surrounding district – regarded as especially vulnerable - to areas which were strategically safer. At the same time, as the Air Ministry ruefully admitted, absolute safety was becoming increasingly impossible as the range of aircraft developed.[46]

In the case of shadow aero-engine factories, a range of options simply did not exist and it was decided to concentrate the plants in just one city. Fedden, along with other Bristol Aeroplane Company representatives, met with Swinton and Weir in March 1936 to discuss how to implement the shadow scheme. The Bristol delegation wanted each of the shadow firms to produce just one part of the engine: the firms would be educated in the manufacture of relevant components, duplication could be avoided, and variations in design could be introduced. This arrangement, it was said, would be less disruptive to the firms' normal activities. Weir disagreed because he thought there was no time for such a plan. There is also evidence that in organising how the technology - such as the Bristol engine - should be

[44] Jonathan Glancey (2006), *Spitfire: the Biography*. London: Atlantic Books, p.38.
[45] NA, CAB 64/17, Report (Part II), by A.H.R. Fedden, of second visit to Germany, 2-12 Sept. 1937.
[46] CAC, Weir 19/19, minute, 17 June 1935, Bullock to Secretary of State.

transferred from the aircraft companies and set up in the new plants, both Weir and Swinton, deferred to the motor manufacturers.[47]

But the Secretary of State raised his own objections: under Bristol's plans the destruction of one firm by bombing would have jeopardized the entire production process, and he "did not wish to add to the number of cases in which this eventuality was already dangerous."[48] The same argument could also be applied to situations where the sheer volume of production from a single works rendered a whole dimension of rearmament vulnerable. Weir argued that this was the case with the Rolls Royce aero engine plant in Derby and that, consequently, a shadow factory located elsewhere (but operated by Rolls Royce) was justified.[49] Similarly, when deciding on additional airframe shadow capacity at the end of 1937, Swinton ruled that the factories had to be located in safe areas since there could be no excuse for spending public money in establishing them in vulnerable areas.[50] Thus, the British government recognised, albeit implicitly, that basing the shadow aero engine scheme in one major centre would risk turning it into a primary target for the enemy. Herein lay something of a strategic gamble: that the benefits of harnessing the motor industry – the rapid expansion of a fleet of bomber aircraft acting as a deterrent – would mean that the costs resulting from enemy action would not have to be faced. It was a gamble which was not, of course, to pay off: Hitler was not deterred and Coventry was devastated.

2.3 Opposition of the local population

The history of how shadow factories were developed in Britain reveals a curious paradox. In principle, building a new factory meant a welcome increase in employment opportunities within a region; in practice, the precise sites selected for the new factories frequently stirred up a great deal of local controversy, even anger. The local authorities of the so-called "Special and Depressed Areas" engaged in intense lobbying to secure rearmament-based jobs for their regions rather than for the prosperous southern half of Britain. So many requests were received that an inter-departmental committee was set up, in 1937, to examine the issues around the location of new munitions factories. The government felt compelled to declare that

[47] Sebastian Ritchie, Industry and Air Power: the Expansion of British Aircraft Production, 1935-41 (London, 1997), p.59.
[48] CAC, Weir 19/15, Notes of 32nd Progress Meeting, 13 March 1936.
[49] CAC, Weir 19/2, Note to Air Member Supply & Organisation, 11 Sept.1936.
[50] CAC, Weir 19/9, Note of Progress Meeting, 17 Dec.1937.

its policy was to establish such factories in depressed areas so far as practical considerations permitted.[51]

By early 1938, the Air Ministry had decided to schedule large-scale production of a promising fighter – the Spitfire - built by the Supermarine Company. This required switching production from other types already being constructed by different aircraft companies and, in order to achieve anything like the required number of Spitfires, adding shadow capacity to those companies. One of the towns selected for this production was Stockport, in Lancashire – the manufacturing-base of the Fairey Aviation Company. The region was both a depressed one and was farther away from an enemy's bombers than many parts of Britain. However, there then followed a protracted dispute over where to put the shadow factory and, once a site was chosen (some redundant works adjacent to Fairey's existing factory), how much land to acquire and whether it should be compulsorily purchased.[52] This district bordered a purely residential area, and preserving the latter's amenities suddenly became a major concern of the Stockport authorities. Chief among these amenities was the Heaton Moor Golf Club. The Ministry's Lands Officer visited Stockport in November 1938 and reported that the Golf Club's secretary was "very much disturbed at the prospect of the greens and tees being taken away". Fortunately, Stockport's Town Clerk was a club member and was asked by the Ministry representative to offer all necessary reassurances to the club committee.[53]

Because the shadow factories built in Coventry under the No.1 scheme were co-located with existing motor vehicle plants, the local authorities raised no objection over the sites and generally supported the scheme. A few residents who lived in newly-built houses close to the Daimler works did object, but the level of local complaints during peacetime appears muted in comparison to the protests accompanying the second phase of the shadow scheme.[54] As war grew near in 1939, and the need to produce a greater quantity of engines became apparent, the No.2 group was established. The four firms involved were organised into two partnerships: Daimler and Standard formed one pair, while Rootes and Rover made up the other.[55] Daimler's management wanted to develop its No.2 factory away from the city, but was

[51] NA, CAB 21/662. The first meeting took place at the Ministry of Labour on 9 Feb.1937.
[52] NA, AIR2/3304, Notes of meeting – Air Council Committee of Supply, 5 May 1938.
[53] Ibid., letter, 18 Nov. 1938, Surveyor's Office, County Borough of Stockport, to E.H.Williams, Lands Officer, Air Ministry, and note by latter, 23 November 1938. The site purchased was that occupied by the Crossley Brothers Works, Heaton Chapel.
[54] NA, AIR 2/1842, statement by residents to the council, 28 Oct. 1937 and letter, 2 Nov.1937, from Town Clerk to Director of Works, Air Ministry.
[55] For background on the schemes see, Thoms, D. (1989). *War, Industry and Society: the Midlands, 1939-45.* London.

instructed to build the plant within five miles of Standard's new Banner Lane works. The site selected was adjacent to Browns Lane in Allesley, a district on the outskirts of Coventry. In late June 1939, the local ratepayers and residents association objected strongly. They had been reassured by the city surveyor that the district was scheduled exclusively for housing; to overturn this, they alleged, would be a grave breach of faith as many other, more suitable sites existed.[56] However, given the intention to concentrate production in order to exploit the benefits of industrial clustering, the existing local infrastructure and facilities, the choice of available sites was limited.

The City Council was itself upset, arguing that ordered planning - the objective of the interwar Town Planning Act - was being thwarted and even made ridiculous by the flagrant disregard of local authorities. The impact of the shadow factory scheme in different parts of the country raised the same issues elsewhere and led to the same kinds of protest. The Crown was not bound by the Act and, therefore, the council had no effective, legal means of complaint or appeal.[57] City councillors told the local Members of Parliament that they understood the "national necessities", but that because of a complete lack of consultation, the choice of sites had been "haphazard" and threatened the establishment of the "green belt". Coventry had been in the vanguard of enshrining this novel principle - of preventing urban sprawl by preserving rural areas around a built-up area - in planning future growth.[58] This now seemed to have been a waste of time and money. Building and operating the two factories involved large-scale capital projects; a new infrastructure of utility supply networks and systems, together with the construction and widening of road systems, were all soon to have a major impact. The council urged the government to set up some effective administrative machinery to avoid a recurrence of actions that were "so contrary to the general public interest".[59] Ironically, the destruction caused by bombing was to give town planners opportunities to redesign an urban environment on a scale scarcely conceivable before 1940. As a result, a 'modernised' city centre emerged after the war.[60]

Rather curiously, the outbreak of war did not force a re-definition of this view of the public interest; if anything, the obvious need to step up the pace of rearmament heightened local

[56] Herbert Trust, Town Clerk's files (hereafter HT), CCA/3/1/7601/1-4, letter, Residents Association to Councillor Myers, 22 June 1939,
[57] ibid., letter, Coventry City Council to Capt. Strickland MP, 28 June 1939.
[58] Green Belts were not formally recognised as part of a national legislative framework until 1955.
[59] HT CCA/3/1/7604/1-16, *Synopsis* , statement by the Town Planning and Buildings Committee, 10 July 1939.
[60] For a discussion see, N. Tiratsoo (1990), *Reconstruction, Affluence and Labour Politics: Coventry 1945-60* London:

concerns. In October and November 1939, directors of both Standard and Rootes wrote to the council over the slow progress of housing development. Rootes were rapidly constructing their No.2 aero engine factory at Ryton. This lay just outside the city to the south, but it depended on Coventry for most of its facilities and amenities. The factory was expected to employ between 4,000 to 5,000 workers. But construction of a large housing-estate adjacent to the factory had come to an halt and Rootes were naturally anxious over how they were going to accommodate their employees.[61]

Whilst the Air Ministry regretted the way the scheme had been imposed, it offered no solutions to the problems. The council believed that a "vast army of additional workpeople" was about to descend on the city. Bodies such as the Engineering Employers' Federation estimated an additional 35,000 workers and 15,000 dependents would migrate to the city in 1940, suddenly swelling the total population from 240,000 to almost 300,000. There was neither anywhere to house these workers nor to attend to their health or educational needs. The Ministry of Health refused to allow permission for an expanded house-building programme, encompassing some 5,000 new houses, because of raw-material shortages. Deploring the apparent absence of any constructive thought by government, the council imagined that the whole future of the city was at stake over how to finance the infrastructure required to meet such a rapid expansion in industrial activity. Worse still, when the war ended and armament production ceased, it was assumed that the unemployed workers would have to be supported by public assistance.[62] The faith expressed in an eventual successful outcome to the conflict was tinged with memories of the recession that has followed the First World War.

At the beginning of 1940, Walter Elliot, Minister of Health, and representatives from all the relevant Ministries met Strickland, the city's MP, and leading council members. The Minister remained unmoved by the deputation's lobbying. He urged the council to make better use of existing houses standing empty and the opportunities for lodging. He pointed out that the City, itself, had asked to be made an "evacuable" area: hundreds of children and other evacuees were being provided for voluntarily, and without resort to compulsory powers under the Defence Regulations, by the inhabitants of surrounding, rural areas. Elliot challenged Coventry's citizens to demonstrate an equal desire to help - by offering accommodation - in work of national importance, whatever the inconvenience and hardship it might cause.[63]

[61] HT CCA/3/1/7601/1-4, letter, 15 Nov. 1939, Col. J.A. Cole (Rootes Securities Ltd) to Town Clerk, Coventry.
[62] HT CCA/3/1/7604/1-16, Coventry City Council, notes, 7 Dec. 1939.
[63] HT CCA/3/1/7601/1-4, letter, Strickland to Elliot, 12 Dec. 1939; memo, Ministry of Health, 5 Jan.1940.

The disputes between local and central government remained unresolved even as Britain faced, by March 1940, what was euphemistically called the "national emergency". Although the government had undertaken to cover all of the costs of new roads required for the shadow factories, the financing arrangements for improving existing roads had been left undecided. The council offered to pay for air-raid shelters, including ones to accommodate the shadow factory workforce, if the government would pay for most of the road improvements; the councillors claimed that "it will be an advantage for the Government and the local authority to work in friendly co-operation."[64] Under the conditions of the "phoney war", local authorities jealously guarded rights related to local autonomy and accountability. There was no sense that Britain's dire geo-strategic situation required drastic remedies. However much the British public supported the mobilisation of resources by central government, local democratic interests did not always sit easily with the dictates and demands of the war.

In sharp contrast to the British case, the German shadow factories were not located in established industrialised centres but in rural, under-developed areas. Consequently, resistance against the establishment of the new armament firms was rather rare. At least in the case of Robert Bosch's planned shadow factory in northern Germany, the towns considered to host the new firm competed with each other for this investment which was finally made in Hildesheim. This is illustrated by a letter in which the chairman of the regional council in Hannover complained bitterly about the fact that Bosch had not supported the proposal by Seelz – one of Hannover's suburbs - even though a rapid supply of both additional housing and cultural entertainment for the new workforce had been promised.[65] The German decision to hide the shadow factories in rural regions obviously had the not unwanted side-effect of diminishing the local opposition to these investment projects.

2.4 Technological transfer

The decision-makers in both Britain and Germany decided against establishing state-run armament firms. Instead, shadow factories were financed and leased to private entrepreneurs because this procedure was the most promising way to make use of the know-how of established manufacturers who knew better than state administrators how to set up and operate these factories. To facilitate knowledge transfer between the parent motor company

[64] HT CCA/3/1/7606, letter, 11 March 1940, to Sir John Nixon (Midlands representative for the Air Ministry) from the Policy Advisory Committee, Coventry City Council.
[65] See Overesch, M. (2008). *Bosch in Hildesheim 1937-1945*. Göttingen: Vandenhoeck & Ruprecht, p. 53.

and the shadow factory, Britain mostly chose – as in the case of aircraft production in Coventry – to locate the latter directly in the neighbourhood of the former. The intention was to bring about external economies in production. It was assumed - not unreasonably for as long as Britain remained at peace - that the parent company's skilled workers and managers would be able to train a greatly expanded workforce coming into the shadow factory to the required high level of efficiency. The large number of ancillary firms in the region would help to facilitate the new production processes. If these aspirations proved difficult to realise before 1940, they were especially challenging under wartime conditions that brought raw material shortages and decision-making that was both arbitrary and increasingly centralised. As a result, shadow factory productivity up to 1942 appears to have been in line with the poor performance of the aircraft industry as a whole.[66]

In Nazi Germany, in contrast, the new shadow factories were often placed hundreds of kilometres away from the traditional location of the armament manufacturer. There is anecdotal evidence that the wide geographical distances between parent company and new subsidiary made knowledge transfer difficult. In the case of Robert Bosch's shadow factory in Hildesheim, for example, the managers had to deal with the problem that the local workforce did not reflect the level of human capital that was needed for the demanding production of starters and dynamos. As a result, Bosch sent master craftsmen from the parent company in Stuttgart to Hildesheim to train unskilled workers – the only ones who were available. This training programme was set up more than one year before production actually commenced in Hildesheim; it was, apparently, made more difficult by the differences in culture, religion and dialect between instructors and trainees.[67]

In general, failed or incomplete knowledge transfer results in a productivity gap between an old and a new factory, which means that the latter needs more labour and other inputs to produce the same amount of output as the former. If geographical distance in fact impedes inter-factory knowledge transfer, the decision to locate shadow factories not in the immediate neighbourhood but far away from the parent company would have led, ceteris paribus, to a comparative disadvantage for Germany in the arms race with Britain. Using the information provided by contemporary audit reports, a preliminary assessment can be made of whether knowledge transfer over long geographical distances was a success or a failure in the war economy of the Third Reich.

[66] Stone, 'Rearmament, War and the Bristol Aeroplane Company', p.194.
[67] See Overesch, M. (2008). *Bosch in Hildesheim 1937-1945*. Göttingen: Vandenhoeck & Ruprecht, pp. 164-166.

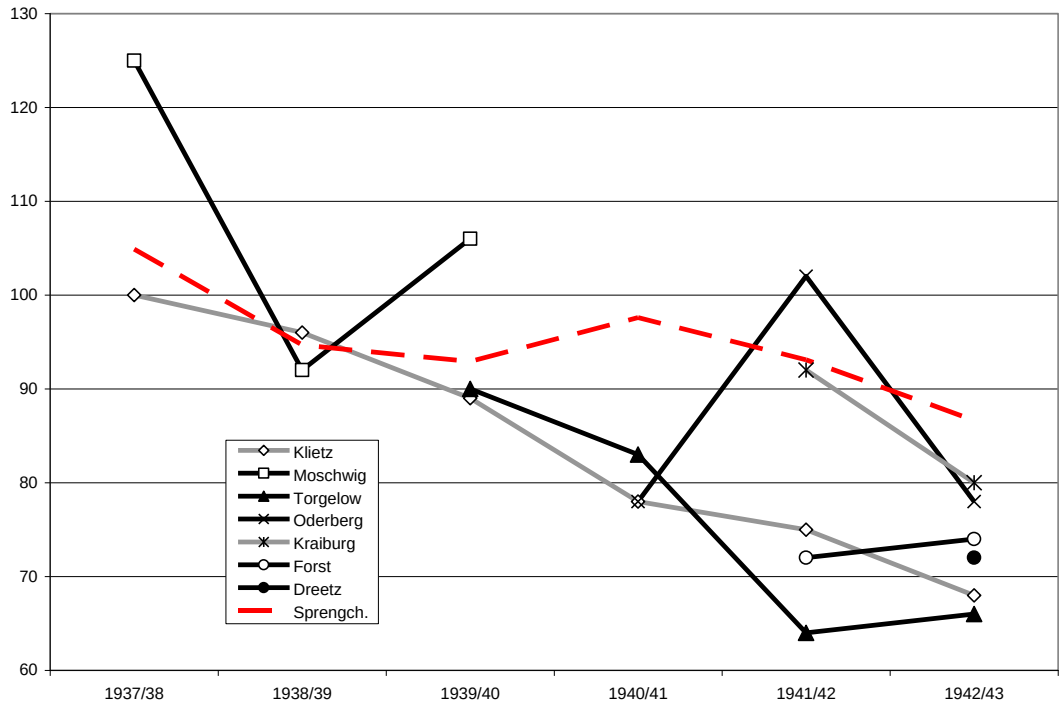
The Federal Archives in Berlin possess a large but seldom used collection of audit reports by the *Deutsche Revisions- und Treuhand AG*. These were undertaken for German firms engaged in armament production before and during the war – among them most of the state-owned shadow factories discussed in this essay.[68] The typical audit report contains not only a comprehensive analysis of a firm's balance sheet and profit-and-loss account but also detailed information about sales, prices, costs and the structure of the workforce. It is particularly fortuitous that among the audit reports are those for the *Deutsche Sprengchemie GmbH* - referred to above - the shadow firm operated by the traditional gunpowder manufacturer *Westfälisch-Anhaltinische Sprengstoff AG* (WASAG). The reports comprise detailed information about every one of *Sprengchemie*'s seven gunpowder-producing works spread out over Bavaria and Prussia and put in operation, step by step, between 1937/38 and 1942/43.[69]

It is not possible to evaluate the extent of knowledge transfer from the parent company WASAG to its shadow firm *Sprengchemie* by comparing their respective labour productivities because the relevant data are, unfortunately, not available. However, this exercise can be carried out for the different works of *Sprengchemie*. The hypothesis is that, first, the managers of a well-established factory learned, while running the works, how to increase labour productivity by technological and organisational improvements, and, secondly, that they tried to communicate this additional knowledge to the management of a new plant, which obviated any need to "learn-by-doing". As a result, a successful knowledge transfer would be indicated by statistical evidence that a new factory started production with labour productivity nearly as high as an actual productivity leader.

[68] The shelf mark of this collection is BArch R 8135.

[69] The direct-line distance in kilometres between Klietz and the other factories was: Moschwig 115, Torgelow 168, Oderberg 135, Kraiburg 501, Forst 205, and Dreetz 30. For more details see Scherner, J. and Streb, J. (2008). Wissenstransfer, Lerneffekte oder Kapazitätsausbau? Die Ursachen des Wachstums der Arbeitsproduktivität in den Werken der Deutschen Sprengchemie GmbH, 1937 bis 1943. *Zeitschrift für Unternehmensgeschichte*, 53: pp. 100-122.

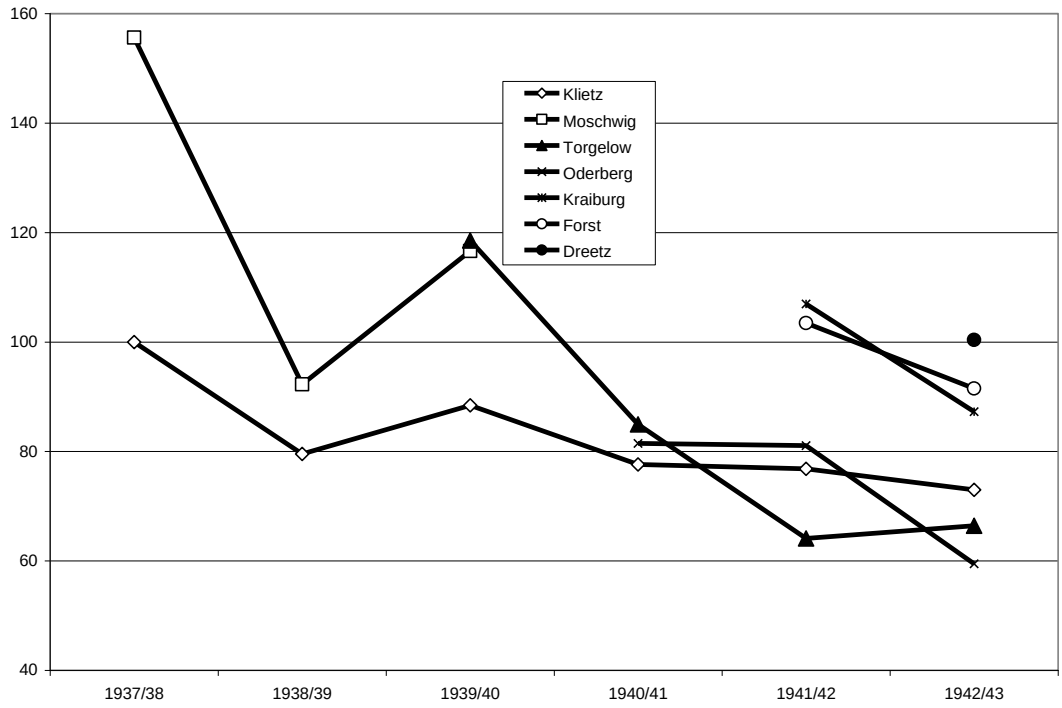
Figure 2 Labour-output ratio in Spengchemie's gun powder works (Klietz: 1937/38=100)



Source: calculations derived from the audit reports of the *Deutsche Revisions- und Treuhand AG*.

Figure 2 shows the historical development of labour-output ratios (the reciprocal of labour productivity) of the seven gunpowder-producing works of *Sprengchemie*. The data suggest, at first glance, that knowledge transfer was successful. The *Torgelow* works started production in 1939/40 with a labour-output ratio (90) nearly as low (89) as that in the same year for the actual productivity leader - *Klietz* - which had begun production with a much higher labour-output ratio (100). A similar observation can be made for the even younger works - *Oderberg* (78 in 1940/41 compared to 78 for *Klietz*) and *Forst* (72 in 1941/42 compared to 64 for *Torgelow*).

Figure 3 Counterfactual Labour-output ratio in Spengchemie's gun powder works (Klietz: 1937/38=100)



Source: calculations derived from the audit reports of the *Deutsche Revisions- und Treuhand AG*.

The difficulty with these findings is that the labour-output ratio is determined not only by (transferred) knowledge but also by the capital endowment of the workforce. All other things being equal, the higher the capital endowment per worker, the higher the worker's labour productivity – and the lower the labour-output ratio. In fact, the capital endowment of the newer works of *Sprengchemie* was in general considerably higher than that of the older works. To try to control for this difference, Scherner and Streb calculated for every factory a counterfactual development of labour-output ratio that would have occurred if the work under consideration had had the same capital endowment per worker as the actual productivity leader.[70] The results are presented in Figure 3. Under the counterfactual assumption of an equal factor endowment in all firms, the evidence for successful knowledge transfer within the shadow firm *Sprengchemie* vanishes. Instead, the works at *Torgelow* (119 in 1939/40), *Kraiburg* (107 in 1941/42), *Forst* (103 in 1941/42) and *Dreetz* (100 in 1942/43) began production with a labour-output ratio that was equal to or even higher than that already achieved at the *Klietz* works in1937/38.

[70] See Scherner, J. and Streb, J. (2008). Wissenstransfer, Lerneffekte oder Kapazitätsausbau? Die Ursachen des Wachstums der Arbeitsproduktivität in den Werken der Deutschen Sprengchemie GmbH, 1937 bis 1943. *Zeitschrift für Unternehmensgeschichte*, 53: pp. 114, 118.

Naturally, care must be taken in interpreting these results. Comparing the development of (counterfactual) labour-output ratios in the different *Sprengchemie* works might reveal that knowledge transfer from factory to factory was difficult, but it does not prove that the difficulties increased with geographical distance. One of the objectives of future research should be to identify and analyse comparable data about (British) parent companies, and their shadow factories that were contiguous or in close proximity, to be able to prove or refute the hypothesis. However, it is possible to reach a tentative conclusion here that the strategy of dispersing German shadow factories across the eastern hinterland might have come with the price that knowledge transfer was made more difficult than in Britain's case. But what appeared to be the right decision for Britain in the late 1930s - to cluster a high proportion of strategically-vital production in a confined urban area – seemed sheer folly once war had actually broken out.

Allied fortunes suffered a disastrous reversal with the Fall of France. In planning air-raid protection, the Coventry authorities seemed to recognize that the shadow factory workforce and the general population were equally vulnerable. Certainly, the Standard and Daimler works were among the armaments factories specifically targeted by the Luftwaffe on the night of the Coventry blitz (13/14 November 1940). Daimler's No 1 factory in Radford was singled out for particular punishment - it was hit by an estimated 150 HE bombs and 3000 incendiaries. However, during the 11 hours the raid lasted, 43, 000 homes were destroyed or badly damaged and 554 people killed across the city as a whole. In its intensity the raid was without precedent. It is not the case that the city's defences had not been neglected: with over 40 anti-aircraft guns in action, Coventry was as well protected as anywhere in Britain at that stage of the war. But, the vagaries of ground gun-control, and the inability to deploy radar-equipped night fighters, allowed all but one of the German raiders to escape unharmed.[71]

With much of Daimler's factory severely damaged, the Air Supply Board discussed measures for the dispersal of production.[72] Consequently, the big raid, and another destructive one in April 1941, interrupted the policy of localisation; a limited number of shadow factory units and departments were dispersed to minor industrial centres and rural areas. It is difficult to quantify production losses at Coventry's shadow factories as a result of the bombing, but stoppages proved to be temporary. Repairs to the infrastructure (under the leadership of

[71] Colin Dobinson (2001), *AA Command: Britain's anti-aircraft defences of World War II* London: Methuen. p. 271
[72] NA, AIR 2/1842, minutes 9 Dec. 1940.

William Rootes) were made a priority. Furthermore, as the bombing of Germany later confirmed, factory machine tools were difficult to destroy and could be repaired. Similarly, pessimistic predictions in the immediate aftermath of the 1940 raid were not realised: civilian morale did not collapse. Nonetheless, a proportion of the population left the city, making available undamaged accommodation for the shadow factory workforce. This allowed the authorities to continue a process of voluntary billeting - much as the government had urged. In addition, by 1943 the Ministry of Labour had built 16 hostels with 8,000 places for workers in Coventry and south-east Birmingham.[73] The city remained, therefore, a key centre for the war effort.

3 Conclusions

The claim advanced in this essay is that to understand the similarities and differences between the war economies of Second World War combatants it is necessary to look, first, at the underlying economic problems all countries had to deal with, and, secondly, at the particular national solutions each country found for these problems. Applying this research concept to an analysis of the business history of shadow factories in Britain and Germany yields some important and surprising results. Despite all ideological and political differences, the governments in both countries shared a common goal to build up additional capacity for producing armament goods before the actual outbreak of war. Their common problem was that the relevant private firms in both countries judged an investment in additional or new armament factories as very risky and unprofitable in the longer run; consequently, they declined to use their own funds for these investment projects. Given the choice between establishing state-run shadow factories and leasing state-funded shadow factories to private operators both governments opted for the second solution. This decision was driven by the idea, again shared by both governments, that in contrast to the state, the traditional manufacturers of armaments and vehicles had the know-how to build up and operate these new factories.

Differences occurred with respect to where the shadow factories were located. In Britain, the new factories were often placed in the immediate geographical neighbourhood of the parent motor company while, in Germany, the shadow factories were mostly located far away from traditional industrial centres. Both solutions had advantages and shortcomings. The German solution had two, main advantages: first, the shadow factories could be hidden in rural areas,

[73] Shenfield & Sargant Florence (1944-45), 'The Economies and Diseconomies', pp. 96-7.

or even forests, reducing their vulnerability to attack from French and British bombers; secondly, local governments did not oppose these investments which often promised to take the form of a modernisation programme for their underdeveloped regions. There was, however, a major shortcoming in the German strategy: the large geographical distance between parent company and new subsidiary, as well as the insufficient supply of skilled workers in rural regions, might have impeded knowledge transfer and, in turn, reduced labour productivity in shadow factories in comparison to the armament manufacturers' established works. The British approach to setting up shadow production led, of course, to advantages and shortcomings that were diametrically opposite to the German ones.

Despite these differences in the details of the British and German shadow schemes, the fundamental solution to the underlying economic problem – how to utilise the know-how of private armament and other manufacturers who were unwilling to invest - was the same in both countries. This finding suggests that in both countries armaments policy was driven less by ideological objectives and rather more by economic necessities. In a broader perspective, the task of fighting a material-intensive modern war, such as the Second World War, might have led to very similar, national solutions for shared, economic problems. This essay offers a framework for analysing these developments by conceptualising them in terms of an international model of the war economies of the 1930s and the Second World War.

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