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British and German Manufacturing Productivity Compared: A New Benchmark for 1935/36 Based on Double Deflated Value Added

RAINER FREMDLING, HERMAN DE JONG, AND MARCEL P. TIMMER

We present a new estimate of Anglo-German manufacturing productivity levels for 1935/36. It is based on archival data on German manufacturing and published British census data. We calculate comparative levels of value added, correcting for differences in prices for outputs and inputs. This so-called double deflation procedure provides new insights into productivity comparisons because output- and input price structures differed greatly between the two countries. Although the new calculations confirm existing results at an aggregate level, they reveal important differences at the industry level and show how Germany was striving for autarky as it prepared its economy for war.

The reunification of German archives has offered historians easier access to the records of the Imperial Statistical Office (*Statistisches Reichsamt*), which is now housed in Berlin-Lichterfelde (West). Recent historical research in these archives has unearthed important new information from the German industrial census of 1936, which not only permits a reevaluation of German growth in the twentieth century but also makes possible a more careful comparison of British and German industrial productivity in the interwar years. In particular, the new detailed data make it possible to undertake comparisons of real value added at detailed industry levels using the theoretically appropriate double deflation technique.¹ It is widely acknowledged that double deflation is the preferred approach for sector comparisons of output and

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¹ "Value added" is sometimes denoted by "net production value," but we prefer the former term as it is consistent with the terminology in the System of National Accounts. In addition, we use the term deflation for both intertemporal and interspatial comparisons.

productivity because it takes into account relative prices for intermediate inputs, alongside relative prices for gross output.²

Existing international comparisons of productivity in manufacturing for the pre–World War II period relied either on direct quantity comparisons or on single deflation, using relative output prices to convert value added into a common set of prices.³ For example, Stephen Broadberry and Rainer Fremdling reworked a Germany–United Kingdom comparison for 1935 by Laszlo Rostas, which was mainly based on physical quantities. The primary obstacle for double deflation has been the paucity of comparative price data on intermediate inputs, such as materials, energy, and services. In recent years, however, the archival records that formed the basis of the published version of Germany’s 1936 industrial census have been rediscovered.⁴ As early as in the 1940s, Rostas knew what such archival material would make possible. In his comparison of Germany and the United Kingdom, he remarked that “. . . a revision of these figures could be undertaken when the detailed reports of the 1936 German census of production become available in this country.”⁵ In the 1990s the underlying data records (*Produktionserhebungen*) of the German census of 1936 were finally found in the *Bundesarchiv* in Berlin. These data allow us to make the new comparison of British and German manufacturing in 1935/36, which differs from the existing estimates in three ways. First, the newly available data allow us to calculate value added and labor productivity for 109 industries in Britain and Germany, covering the entire manufacturing sector. Second, we can convert everything into a common currency by using price ratios derived for each industry in Britain and Germany from data on quantities and values of gross output. Third, the available data on intermediate input items make it possible to adjust for intermediate input price levels as well and to carry out a double deflation analysis in a clearly defined conceptual framework.

Our results show that opting for double, rather than single, deflation is not merely the choice of a more sophisticated technique. If firms in different countries were to face similar competitive conditions in both internal and external markets (as firms would, for example, under con-

² See for example Paige and Bombach, *Comparison*, p. 82. Although the authors advocated the methodology of double deflation, in practice they did not implement it in manufacturing. See also Broadberry, *Productivity Race*, p. 23. For a long time, double deflation has been the standard procedure for measuring volume changes in value added over time by statistical offices.

³ See Broadberry and Fremdling, “Comparative Productivity”; Broadberry, “Anglo-German Productivity Differences” for United Kingdom–Germany comparisons. Other comparisons will be discussed in what follows.

⁴ Reichsamt, *Die deutsche Industrie*.

⁵ Rostas, *Comparative Productivity*, p. 40.

ditions of a liberal foreign trade regime and a corresponding currency policy), then relative gross output prices might move in tandem with intermediate input prices, as assumed in single deflation. During the 1930s, however, Germany strove for autarky in order to prepare its economy for warfare.⁶ Its increasingly restrictive foreign trade regime and tight currency controls thus detached the internal price level and structure from world market relations, whereas Britain was pursuing a comparatively moderate protectionist tariff policy. It is therefore no surprise that our calculated relative price levels deviated significantly from the official exchange rate between the German Reichsmark and the British Pound. The divergence not only led to different price levels but to different price structures and ratios between input and output prices in the two countries' industries. Clearly in our case the basic assumption for *single* deflation is violated, and both input and output prices have to be taken into account in order to arrive at adequate relative prices and meaningful productivity comparisons.

Table 1 presents our major results: it compares labor productivity (real value added per worker) in the United Kingdom and Germany for manufacturing as a whole and for different branches of industry. It is derived using newly calculated relative prices and both for *single* and *double* deflation. According to the table Germany had a labor productivity advantage of 5 percent with *single* deflation and 7 percent with *double*. Thus on the aggregate level of manufacturing as a whole, both countries had similar labor productivity. Across specific branches of industry, however, there were widespread differences in labor productivity between the two countries. And the magnitude of these differences was sensitive to whether *single* or *double* deflation was used.

The choice of *single* or *double* deflation did not greatly change the rank order of comparative productivity levels among industrial branches. But Anglo-German differences did become more pronounced in most cases (7 out of 12), with double deflation, and in two instances the comparative performance was even reversed. In particular, German performance in textiles and leather fell much further below British achievements with double deflation. With food manufacturing, however, double deflation raised German labor productivity by taking into account the relatively high German prices of intermediate inputs, such as wheat, brought on by tariffs and the German government's agricultural policy.⁷ Our

⁶ See the recent detailed studies by Ebi, *Export*, on foreign trade; and by Höschle, *deutsche Textilindustrie*, on a specific industrial branch. On the management of the war economy before and during the war see Müller, *Manager*; and Geer, *Markt*.

⁷ Two recent articles analyzed the severe consequences of high and rising food prices for the standard of living in Germany. Steiner, "Neueinschätzung"; and Baten and Wagner, "Mangelernährung"; see also Abelshauser, "Germany," pp. 143–47.

TABLE 1
LABOR PRODUCTIVITY PER BRANCH IN MANUFACTURING: UNITED KINGDOM
AND GERMANY, 1935–1936

	Value Added per Worker (Germany as percentage of United Kingdom)	
	Single Deflated	Double Deflated
Textile trades	96.7	76.2
Leather trades	72.7	47.1
Clothing trades	93.5	93.4
Iron and steel trades	133.5	175.1
Engineering, shipbuilding, and vehicles trades	112.3	106.1
Nonferrous metals trades	133.4	103.9
Food, drink, and tobacco trades	68.3	77.8
Chemical and allied trades	111.2	125.5
Miscellaneous trades	99.8	94.6
Clay and building materials trades	97.7	105.7
Paper, printing, and stationery trades	102.9	141.0
Timber trades	151.0	90.1
Total manufacturing	105.4	106.8

Source: Data are from Fremdling, de Jong, and Timmer, "Censuses Compared." www.ggdc.net.

double-deflated estimate of German comparative performance in food processing was thus much higher than those obtained from quantity comparisons or single deflation. Double deflation also made the German advantage in chemicals and paper much clearer, because it corrected for relatively high intermediate input prices in Germany. It did the same for the metal industry, giving Germany much higher labor productivity in iron and steel, but little advantage in other metallurgical sectors.⁸

Although the aggregate results do not depart significantly from previous estimates, the figures for particular industries are strikingly different. If our comparison is used as a new benchmark for time series projection, its effects will be ambiguous. They will depend on how our aggregate results are linked to aggregate indices of manufacturing or on how the estimates for the industrial branches presented here are tied to time series of productivity for each industry.

SOURCES AND DATA

In general, production censuses provide the best data for productivity comparisons. Based on one and the same source, they give information on gross output (quantities and values of products), value added, and

⁸ An increasing intervention and regulation of the iron and steel branch was put forward by Geer, *Markt*. For price distortions in 1936 see pp. 39–45.

employment, which guarantees internal consistency. For the United Kingdom, we took the *Census of Production* of 1935, which was published by the Business Statistics Office (BSO) of the Board of Trade.⁹ The data on Germany are based on the industrial census of 1936. One well-known disadvantage of using census data is that production censuses often omit production data from smaller firms. If the omissions are more severe in one country, comparisons involving them may be inconsistent. Countries may also differ in their definition and concepts of gross output, intermediate input, and employment. In this section, we provide a rough estimation of possible differences in coverage and concepts between the German and British censuses.

In this study, we do not draw on the *published* version of the German census but on the comprehensive *archival records* of the German data. We do so for four reasons. First, for military reasons, some branches of industry were hidden by classifying them under misleading headings or by applying a high level of aggregation in the official publication. Second, the archival records give more detailed information on a lower level of aggregation, which makes it easy to fit the German industries into the classifications used in the U.K. census. Third, the published German census provides labor force data only for a single month of the year (usually June), whereas the archival records give the same information for two months (usually June and December). The archival records thus permit precise estimates of labor input and labor productivity. Finally, the archival records provide detailed accounts of the quantities and related values of inputs and outputs for many different manufacturing industries. This allows us to calculate average unit values for a large number of items, which a robust comparison with the UK requires. Because of these characteristics of the unpublished archival records we believe the figures on Germany that we present in this paper are superior to the official census figures published in 1939. Before starting with the comparison of data from this source with the British census of 1935, we will describe the historical background of the German industrial census of 1936, its publication in 1939, and the archival records in some detail.

The German Industrial Census of 1936 and its Publication in 1939

In 1939 the German Imperial Office for Military-Economic Planning (*Reichsamt für Wehrwirtschaftliche Planung*) published its first and only report on the official Census of Production: *Gesamtergebnisse der*

⁹ Board of Trade, *Final Report*.

*amtlichen Produktionsstatistik – Die deutsche Industrie.*¹⁰ At first sight, it seems both comprehensive and detailed and seemingly covers all of German industry, with 30 industrial branches and a number of sub-branches. In addition to value added, it offers information on employment, wage bills, sales, and foreign trade.¹¹

Surprisingly, the report admits that the industrial census of 1936 was used for planning the war. With this in mind, one wonders why the German Imperial Office published the information at all. Such a publication was not undisputed of course. The central command of the army accused the Imperial Office of having violated secrecy by publishing the report. It demanded that the data be removed from public access.¹² Although publication of statistics was restricted, the Imperial Ministry of Economics had approved the report, because it fell within the guideline of what was permissible. This guideline did not recommend that data be deliberately falsified. On the contrary, in February 1939 it was stipulated: “. . . all publications should still tell the truth. In case of doubt, the publication of statistical and other details should be dropped rather than to report wrong details.”¹³

A comparison of the published data of the Imperial Office with the records reveals that the published data seem to be reliable, at least at first glance. For reasons of camouflage, however, certain industries considered important for warfare were hidden by the way the data were aggregated. Basically, the data had been collected for individual plants or industrial units (*Betriebsstätten*). They then were aggregated by industrial branch. For the sensitive iron and steel industries, for instance, the published statistics covered the entire branch, whereas the archival records distinguished four separate industries. For chemicals, the publication distinguished only seven industries, whereas 38 were noted in the archival records. In addition, certain industries were hidden under misleading aggregates. The foremost example is the aircraft industry. It was supposed to fall under the category of “vehicles” (*Fahrzeugindustrie*) but it ended up hidden under “construction and others” (*Bauindustrie und sonstige Industriezweige*). As early as 1936, aircraft industry employed at least 135,210 people.¹⁴ This comprised 80 percent of the pub-

¹⁰ Formerly it was the department of industrial statistics of the Imperial Statistical Office (Statistisches Reichsamt). Renamed as Reichsamt für Wehrwirtschaftliche Planung it became an independent institution in 1938. Tooze, *Statistics*, p. 222.

¹¹ For a thorough description see Fremdling, “German Industrial Census”; and Fremdling and Stäglin, “Industrienerhebung.”

¹² Bundesarchiv [hereafter BA] R 3102 / 3082 (letter of 18 August 1939), answers by Leisse 25 August 1939.

¹³ BA R 3102 / 3082 F 9. The Imperial Office had planned further publications.

¹⁴ BA R 3102 / 5922. In BA R 3102 / 5866 even higher employment data are reported.

lished work force (166,534) for vehicles. A similar camouflage was applied to other industries that were considered to have military importance.¹⁵ Due to shifts among industrial branches, notably fuel production, we found further deviations from the published figures in other sectors as well. These are documented in a preliminary input-output table for 1936 covering 16 out of 30 branches of industry.¹⁶ This finding casts more doubt on Walther Hoffmann's reconstruction of German national accounts: For his indices of industrial production and handicraft, he used the published value added figures (*Nettoproduktionswerte*) of the 1936-census as weights in order to compile the aggregate index for the entire time-span from 1850 to 1959.¹⁷

Comparison of the German and the U.K. Censuses

The starting point for our comparison is the classification of the British *Census of Production*.¹⁸ We concentrate on manufacturing, excluding mining, construction works, public utilities, and government industries. For Germany, we draw on the unpublished figures gathered by the Imperial Statistical Office. We arranged the industries into a common classification suitable for a full comparison. The detailed categories in the German archival records allowed us to match each German industry with a corresponding British counterpart. The British census lists 109 separate manufacturing industries or trades. The 284 industries of the German census, covering all manufacturing, were assigned accordingly.¹⁹

The area covered by the British census is Great Britain and Northern Ireland. It includes all productive operations in the United Kingdom. For the 1935 census, the Business Statistics Office followed the same procedure as for the census of 1930. Proprietors employing an average of fewer than ten people a year were not required to report detailed returns. Small firms were only asked to give information on the average number of their male and female employees and the nature of the business. Rostas estimated employment not covered by the general reports

¹⁵ These data concern stocks in cotton industry, "Zündererzeugung" (BA R 3102 / 3082 F37, 30.8.1939), "Schusswaffenindustrie," "Herstellung von Zündstoffen und Sprengkapseln," and "Sprengstoffindustrie." See also Sleifer, "Separated Unity".

¹⁶ Fremdling, "German Industrial Census," pp. 162–65.

¹⁷ Hoffmann, *Wachstum*, p. 389.

¹⁸ Board of Trade, *Final Report*. We did not use the ISIC, to keep as close as possible to the original classification. The British census was the model for the German statisticians. This British viewpoint imputes a British structure to German industry, however, a bias that is unavoidable.

¹⁹ For a detailed documentation see Fremdling, de Jong, and Timmer, "Censuses Compared," www.ggdc.net.

of the census at 536,600 people, which is about 9.4 percent of total manufacturing employment (small and large firms) in that year.²⁰ The total labor force in the U.K. census made up 5,157,587 people. This number is derived from the average number of people/operatives employed during the year (based on monthly figures) and the administrative, clerical, and technical staff (office and management staff) employed in one week in October. Although estimations were made of the number of outworkers, these were not included in the general reports.

The German census data comprise the German Empire (*Deutsches Reich*) within the borders of 1937, thus including Saarland but not Austria and Sudetenland. It basically covered all production units with five employees or more, but in some branches the level of gross output determined what firms were exempt. In several cases, however, all firms were taken into account, for example in mining, fuel, iron and steel, and chemicals.²¹ Sometimes the cut-off point was set at ten employees, for example for bakeries and printing offices.²² Repair shops and sometimes the handicraft sector, for example food processing, were left out. It is difficult to assess the share of employment not covered by the census. According to the workplace census of 1939, about twenty percent of German employees worked in firms with less than 11 people.²³ This may indicate that the left tail of the employment distribution was longer in Germany than in Britain. The German workplace census covered a wider field of total industrial employment, however, including repair work, handicrafts, and even services such as laundries and cleaning. For this reason, it is not easy to reconcile employment data covered by the German industrial census with the actual industrial employment in 1936. From the records in the archive we calculated a total number of 5,969,881 people employed in manufacturing. This is significantly different from what the published version of the census implies. If we apply the same definitions and thus exclude nonmanufacturing employment in construction, mining, quarries and stone-cutting, and utilities, the published record implies 5,874,791 people employed in industry.²⁴ The difference between the two figures is partly explained by certain industries being hidden under the category of “construction and others” in the published census figures. Among them were aircraft production, and some branches of the chemical industry, in total 150,000 workers.

²⁰ Rostas, *Comparative Productivity*, p. 25.

²¹ In these industries, material inputs were considered to be important for warfare.

²² Reichsamt, *Die deutsche Industrie*, pp. 12, 44–55.

²³ Länderrat, *Statistisches Handbuch*, pp. 238–43.

²⁴ Rostas maintained that about 500,000 to 600,000 people deliberately were left out in the reported figures of the census (Rostas, “Industrial Production,” p. 42). We did not, however, find such a gap.

Our calculation with the archival records also canceled out seasonal employment peaks in specific industries. In sugar production and in preserved foods, employment had been overestimated in the published census figures because the number of seasonal workers was reported instead of a representative average for the whole year, as had been done in the United Kingdom. This leads to a downward adjustment of about 55,000 workers. For all German industries, we took the average of June and December as given in the archival records. In cases where the business year did not match the calendar year, two other appropriate months had been recorded.

Appendix 1 describes the remaining sources of potential bias between both censuses resulting from differences in hours worked, in year of comparison, and other factors. The net effect on the comparative productivity level was only on the order of one percent (see Appendix Table 1). Because we aim for maximum transparency we did not make any adjustments in our calculations on the aggregate or industry level, except for duties and taxes. For example in the United Kingdom the excise tax on tobacco was paid for by firms on imports into the United Kingdom and not on sales or gross output, as was the case in Germany. To calculate a figure net of the excise, we estimated duties including subtracted drawbacks on tobacco exports from the United Kingdom and then adjusted both intermediate inputs and gross output accordingly (see Appendix Table 2 for details).

NEW RESULTS FROM DOUBLE DEFLATION

Our method of comparing productivity levels is novel in two ways. First, we use producer prices to deflate value added, instead of using the more common quantity approach. Second, we apply double deflation, meaning that we deflate gross output and intermediate inputs separately, rather than doing a single deflation. To understand our approach a brief survey of existing research is necessary. Basically, two main approaches have been used in comparisons of sectoral productivity across nations: the quantity approach and the price approach. Most benchmark estimates before World War II are based on the comparison of physical quantities of output or related methods. These studies focus on output per worker, and follow the methodology of Rostas. In order to aggregate industries or branches of the economy, employment shares or value-added shares are applied.²⁵ Data availability for the postwar period has allowed a more sophisticated methodology, based on the calcu-

²⁵ Rostas, *Comparative Productivity* and “Industrial Production.”

lation of real output using relative prices, or purchasing power parities (PPPs).²⁶ The price approach is considered superior to the quantity approach because the representation of matched output for nonmatched output is higher for price than for quantity ratios.²⁷ This procedure was popularized by the seminal study of Deborah Paige and Gottfried Bombach in their Anglo-American comparison for 1950.²⁸ It has been applied frequently afterwards in studies for the postwar period, but also in some prewar studies of manufacturing.²⁹ As value added is deflated by a single PPP for output, it is called single deflation.

The crucial element in these studies is the estimation of PPPs for output. These are proxied in two ways: by using final expenditure prices and by using unit values based on values and quantities of produced output.³⁰ Examples of the former include Patrick O'Brien and Caglar Keyder, who calculated purchasing power parities between Britain and France for seven benchmark years between 1785 and 1907, using expenditure prices. Fremdling's Anglo-German comparison for the period 1855–1913 uses six benchmarks based not only on expenditure prices but on unit values as well. Jean-Pierre Dormois compared U.K. and French industrial value added per worker in 1930, using expenditure prices of standard industrial commodities.³¹ Applying expenditure prices to compare value added by industry, however, raises a major problem. Expenditure prices (for example of shoes) do not only reflect costs incurred in the industry in question (shoemaking), but also comprise other costs incurred in the production chain such as transport and trade activities. Therefore expenditure PPPs require adjustments for taxes and subsidies, and for trade and transport margins. In addition, proxies based on expenditure PPPs also need adjusting to exclude the relative prices of imported goods and include the relative prices of ex-

²⁶ The use of the term of “purchasing power parity” in the literature is ambiguous. In the international trade literature, “purchasing power parity” or “PPP” expresses the notion that exchange rates in the world should be such that it is possible to purchase the same bundle of goods and services anywhere in the world with, say, one dollar or one pound. In the work of the International Comparisons Program, the term of “PPP” was diluted and used as a shorthand for the ratio of expenditure prices across countries (Kravis, “Survey”). Ever since, “PPP” has been used as a shorthand for relative prices across countries. We follow this tradition by using the term of “PPP” for any comparison of prices across space, either expenditure, producer output, or input prices.

²⁷ Kravis, “Survey,” p. 4.

²⁸ Paige and Bombach, *Comparison*.

²⁹ See van Ark, *International Comparisons*, for an overview of comparisons for the postwar period.

³⁰ For comparisons of agricultural output it is sometimes feasible to derive PPPs on the basis of genuine producer output prices, but not for manufacturing, which has a much larger set of goods.

³¹ O'Brien and Keyder, *Economic Growth*, p. 44; Fremdling, “Productivity Comparison,” p. 32; Dormois, “Episodes,” p. 345; see also Broadberry, *Productivity Race*.

ported goods, as they should reflect domestic output prices. And most important, the set of products for which expenditure prices are available does not cover intermediate products such as many agricultural, mining, and basic manufacturing goods, which are only used as intermediate inputs, and not for final consumption (for example pig iron, paper pulp, or basic chemicals). Hence the use of expenditure prices is not straightforward. Instead, output prices are to be preferred conceptually. They have been used extensively in the ICOP (International Comparisons of Output and Productivity) project at the University of Groningen, but mostly for the post-1970 period.³² Our study is in this tradition.

Applying the Double Deflation Method

So far, all previous historical studies in the price tradition have relied on a single deflation procedure, deflating value added by a single PPP for gross output. The single deflation method, however, is “not so tidy and conceptually less satisfying.”³³ It is well known that the theoretically correct procedure would be to obtain data on gross output and intermediate inputs in both countries and to convert them to a common currency using separate PPPs for output and intermediate inputs. Single deflated measures may differ substantially from double deflated measures when there are major differences in the technical input-output coefficients of an industry between two countries. This might be due to, for example, differences in production methods, the type of materials used, and the amount of imported material. Similarly, when relative prices of output and input differ across countries, single deflated productivity measures might be misleading.

To illustrate this, we provide a very simple example of productivity comparisons based on single and double deflation.³⁴ Consider a comparison of the production of a single well-defined homogeneous product in two countries. Assume, for simplicity, that only labor and intermediate inputs are needed for production, and that the production process in both countries is identical, using the same quantities of labor and intermediates per unit of output. Note that by construction, there is no difference in productivity between the countries. Further, assume that the relative prices of labor and intermediates between the two countries differ. To make this example specific, suppose that in both countries it

³² See van Ark and Timmer, “Notes and Communications,” for an elaborate discussion. For ICOP studies for the postwar period, see www.ggdc.net. See de Jong, *Catching Up Twice*, p. 37, for a prewar comparison of Dutch labor productivity levels with levels in the United Kingdom and Germany using output unit values derived from census data.

³³ See Paige and Bombach, *Comparison*, p. 82.

³⁴ We thank the editors for this suggestion.

takes one unit of intermediate input and one unit of labor to produce one unit of output. Also assume that the prices of labor and intermediates in the base country (United Kingdom) are £1 per unit. In the other country (Germany) labor costs RM20 per unit, however, and intermediates RM40. This implies that the output price per unit in the United Kingdom and Germany must be respectively £2 and RM60 in order to cover the cost of production.

Let us now undertake a labor productivity comparison based on value added (value of output minus value of intermediate input) and single deflation. U.K. value added at U.K. prices is £1 ($= £2 - £1$) and German value added at German prices is RM20 ($= RM60 - RM40$) and we need to have a relative price to convert the latter into pounds. With single deflation, we implicitly assume that the output PPP of RM30/£ ($= RM60 / £2$) is equal to the value added PPP and calculate that real value added in Germany in U.K. prices is £0.67 ($= RM20 / RM30 / £$). This in turn implies that productivity in Germany is two-thirds the level of productivity in the United Kingdom, which, by construction of the example, is wrong. Double deflation corrects this problem by separately deflating output and intermediate inputs with different PPPs. The intermediate input PPP is higher than the output PPP: RM40 / £ ($= RM40 / £1$). Thus RM40 intermediate input in Germany deflated by this PPP yields £1. Likewise RM60 of output deflated by relative output prices yields £2, and the real value added in Germany in U.K. prices is £1. This is identical to the U.K. value added, and hence productivity is the same in both countries, which is of course the correct answer. In more complex cases with more inputs (such as capital and other intermediates) and outputs, a similar story holds, but standard index number issues will arise that will yield different answers depending on which country's prices are used as the base in the calculation.

The results in the previous paragraph can also be obtained by deflating the German value added by an appropriate value added PPP. This PPP is the ratio of value added in Germany at U.K. prices (as we calculated in the previous paragraph) to the nominal value added in German prices. Writing the algebra quickly shows that this yields the same results as the direct comparison (see Appendix 2). In the presentation of our results in this article, we proceed by calculating value added PPPs and deflating nominal value added.

There are two main reasons why double deflation has not been applied in practice so far: lack of price data on intermediate inputs and possible volatility of the deflated value added measure. Because value added is the residual between real output and real intermediate input, which have been separately deflated, measurement errors in either set of

prices tend to be magnified.³⁵ In this study, however, we have a set of unit values for both gross output and intermediate inputs for Germany and the U.K. at our disposal. The unit values are taken as proxies for output and intermediate input prices. And the results show that double deflation is feasible, generating reliable results in line with expectations.

Unit values are derived by dividing ex-factory output values by produced quantities for a set of common products in both countries. The unit value can be considered as an average price, averaged throughout the year for all producers and across a group of similar products and sold in domestic as well as foreign markets, thus including exports. Subsequently, in a bilateral comparison, broadly defined products with similar characteristics are matched, for example boilers, cigarettes, margarine, and car tires. For each matched product, the ratio of the unit values in both countries is computed. These product-level unit value ratios need to be aggregated to derive industry-level PPPs. In this aggregation we encounter the familiar index number problems and we deal with them in an appropriate manner (see Appendix 2 for mathematical details). The weights used in aggregation are calculated directly from the British and German census data, both for input and output weights.

PPP Results

We started from estimating the unit value ratios by matching products between the United Kingdom and Germany. Both in the U.K. census and the archival records of the German census, there is a wealth of information on the product level to calculate average prices. For output, it was possible to match 229 products ranging from cotton yarn to various chemical products, for all branches of industry.³⁶ Table 2 shows the coverage ratios (the share of total gross production value covered by products for which a match could be made) in the United Kingdom and Germany. For total output, coverage ratios are 42 percent, for both countries. The numbers of matches as well as coverage ratios differ across branches, which is explained by the availability and heterogeneity of products, by differences in quantity specifications (units of measurement), the unique national character of some products and by differences in quality across countries. The largest number of product matches (57 matches) was achieved in chemicals, due to detailed product specifications in the censuses. In textiles and food we arrived at

³⁵ See Geary, "Concept," p. 258; and Paige and Bombach, *Comparison*, p. 81.

³⁶ A detailed list of all products and related values/weights can be found in: Fremdling, de Jong, and Timmer, "Censuses Compared," see www.ggdc.net.

TABLE 2
COVERAGE RATIOS AND NUMBER OF PRODUCT MATCHES PER BRANCH IN MANUFACTURING: UNITED KINGDOM AND GERMANY,
1935–1936

	Gross Output PPP			Intermediate Input PPP		
	Coverage Ratio of Gross Output		Number of Products Matched	Coverage Ratio of Gross Input		Number of Products Matched
	Germany	United Kingdom		Germany	United Kingdom	
Textile trades	52.9	50.3	14	46.5	68.1	14
Leather trades	34.9	36.2	6	20.4	24.1	5
Clothing trades	36.8	27.6	5	52.7	51.3	7
Iron and steel trades	45.1	39.9	30	29.8	30.6	10
Engineering, shipbuilding, and vehicles trades	28.9	31.1	45	25.4	24.9	21
Nonferrous metals trades	43.3	66.2	15	7.3	22.6	7
Food, drink, and tobacco trades	67.8	62.5	23	53.5	34.4	16
Chemical and allied trades	35.2	41.5	57	16.2	20.1	28
Miscellaneous trades	29.1	29.0	8	39.3	35.5	5
Clay and building materials trades	52.0	42.9	13	18.1	18.3	6
Paper, printing, and stationery trades	20.3	20.6	10	28.7	22.3	6
Timber trades	29.2	16.5	3	47.8	36.2	4
Total manufacturing	42.8	42.4	229	35.0	37.4	129

Note: Coverage ratio is defined here as the share of output and input values covered by products for which a match could be made.

Source: Data are from Fremdling, de Jong and Timmer, "Censuses Compared." www.ggdc.net.

coverage ratios above 50 percent. Coverage ratios were low in paper (printing products could not be matched) and wood products. Because the size of these branches is relatively small, their weight in the average ratio for total manufacturing is also small. Engineering is a special case in our sample. Traditionally, engineering has always been a very difficult sector in benchmark studies because of the large variety in machines due to customized production. In the present case, both the British and the German census contain detailed lists with quantities and values of many types of machines, including locomotives and diesel engines. We were able to match 29 different types of machines, thereby enhancing the reliability of the outcome.

Because we want to employ double deflation, we also matched intermediate inputs. The assumption that the unit value ratio for the matched products is representative of all the unmatched products is harder to make than in the case of outputs, because of the heterogeneity of intermediate inputs. There are, however, many examples of inputs that are recorded for several classes of semi-manufactured products that cover a large fraction of intermediate inputs. This is especially the case in textiles and clothing, with coverage ratios between 46 and 68 percent (see Table 2). In total, 129 matches could be made with a coverage ratio of 35–37 percent for total manufacturing. We were not able to match quantities and values of fuel and electricity because the German census only records the value of the fuel consumption but no related quantities. In many industries, however, the fuel bill is a small fraction of total intermediate input, in most cases less than 5 percent.³⁷ Given all the prices we collected, it would be a mistake to give up on double deflation on the grounds that there were “insufficient data on input prices to obtain reliable double deflated estimates. . . .”³⁸ We in fact did manage to gather the data that theory required.

Table 3 provides the gross output, value added, and intermediate input PPPs resulting from the calculations according to the methodology described. We present the Laspeyres, Paasche, and Fisher PPPs that result from our binary comparisons. The ratios differ across industries. Output PPPs are high in the textile, leather, clothing, and food industries. In these industries producer output prices were higher in Germany than in the United Kingdom. In 8 out of the 12 branches the Laspeyres PPP is higher than the Paasche PPP, implying that relative German prices are higher with British weights than with German weights. This is the standard Gerschenkron effect. In a two-country comparison, the Gerschenkron effect implies that the use of quantity weights of one

³⁷ Paige and Bombach, *Comparison*, p. 193.

³⁸ Broadberry, *Productivity Race*, p. 23. He refers to Paige and Bombach and van Ark.

TABLE 3
GROSS OUTPUT, VALUE ADDED, AND INTERMEDIATE INPUT PPP PER BRANCH IN MANUFACTURING: UNITED KINGDOM AND GERMANY, 1935–1936

	Gross Output PPP (RM / £)		Intermediate Input PPP (RM / £)		Value Added PPP (RM / £)		Value Added PPP as Percentage of Gross Output PPP
	Laspeyres	Paasche	Laspeyres	Paasche	Laspeyres	Fisher	
Textile trades	21.8	21.5	21.6	18.8	18.7	18.7	27.5
Leather trades	28.6	27.9	28.2	21.8	21.9	21.8	43.6
Clothing trades	22.0	21.5	21.7	21.7	21.7	21.7	21.8
Iron and steel trades	14.9	15.2	15.0	17.9	17.9	17.9	11.5
Engineering, shipbuilding, and vehicles trades	17.8	17.3	17.6	16.3	16.5	16.4	18.6
Nonferrous metals trades	14.6	16.3	15.4	12.4	15.1	13.7	19.3
Food, drink, and tobacco trades	24.3	24.5	24.4	26.3	26.5	26.4	21.0
Chemical and allied trades	17.2	16.3	16.7	18.7	18.4	18.6	15.4
Miscellaneous trades	19.9	18.9	19.4	18.1	18.7	18.4	14.3
Clay and building materials trades	16.0	15.3	15.6	18.3	18.3	18.3	19.2
Paper, printing, and stationery trades	14.8	14.1	14.5	21.5	21.6	21.6	14.3
Timber trades	10.2	10.2	10.2	6.9	6.7	6.8	10.6
Total manufacturing	19.3	17.6	18.4	19.6	18.2	18.9	22.1
					18.8	17.0	17.9

Note: The last column shows the ratio of the (Fisher) value added PPP to the (Fisher) gross output PPP.

Source: Data are from Fremdling, de Jong and Timmer, "Censuses Compared." www.ggdc.net.

country will lead to an overstatement of the other country's prices, the more the price structures of the two countries differ.³⁹ This effect occurs because goods with a high (low) price in one country relative to the other country are associated with relatively small (large) quantities. Interestingly, we do not find a Gerschenkron effect in iron and steel, nonferrous metals, or food processing. The nonexistence of a Gerschenkron effect for these industries implies that consumer preferences are not fully reflected in price setting. Similar findings were reported for (former) centrally planned economies in the 1980s.⁴⁰ This clearly suggests distortions in the price formation and production allocation process in Germany in 1936.⁴¹ Using our deflation procedure thus adjusts for administrative price setting and reveals the real effects of the distortion of the German price vector.

The intermediate input PPPs show a large cross-industry variation too. We find above-average PPPs in leather, clothing, food, and paper. The first three industries also show high output PPPs. In the food industry we find relatively high German input prices for items such as wheat, barley, milk, and unrefined sugar. Germany protected its agricultural sector and therefore relied heavily on relatively expensive home production, whereas Britain imported cereals from overseas. For intermediate inputs, the Laspeyres and Paasche indicators move very close together, the only exception being nonferrous metals. The implication is that individual industries in both countries used similar quantities of intermediate inputs.

Using both output and intermediate input PPPs in equations 8 and 9 of Appendix 2 we now can calculate the double deflated value added PPPs. The results for the value added PPPs are also given in Table 3. Again the difference between Laspeyres and Paasche is small. Using the structure of the branches of manufacturing in Germany or the United Kingdom does not make much difference. The overall Fisher value added PPP is RM17.9 / £. We can compare this figure with alternative estimates. It is, for example, very close to a PPP of RM17.1 / £ calculated by the *Institut für Konjunkturforschung* for the year 1935.⁴² And it is well above the (overvalued) official exchange rate of RM12.3 / £.⁴³

³⁹ Gerschenkron, "A Dollar Index."

⁴⁰ See van Ark, Monnikhof, and Timmer, "Prices."

⁴¹ The studies by Geer (*Markt*, pp. 40–41); and Höschle (*deutsche Textilindustrie*, pp. 60–66) present direct evidence of price regulations by the government.

⁴² This PPP was taken from the *Institut für Konjunkturforschung* (Institute for Business Cycle Research later named *Deutsches Institut für Wirtschaftsforschung* DIW). In their *Wochenbericht* (12, 1939 No. 25) industrial production of the United States and United Kingdom were compared with Germany. It is not clear in which way the converter was calculated precisely. In any case they took an exchange rate of the past, probably the gold exchange rate of 1929 and adjusted it for price movements until 1935, the year of comparison.

⁴³ Exchange rate from Svernilson, *Growth*, p. 318.

The last column of Table 3 gives the ratio of the (Fisher) value added PPP to the (Fisher) gross output PPP. This ratio reflects the productivity of capital and labor in the production process. A higher PPP for output than for intermediate input (as with textiles) may indicate that the German textile industry faces higher costs (labor costs, capital costs, or profit margins) than the U.K. industry. The higher costs yield a value added PPP that is larger than the gross output PPP. In 4 out of the 12 branches, the value added PPP is substantially higher than the gross output PPP: textiles, leather, nonferrous metals, and wood products. For iron and steel, and paper and printing, value added PPPs are much lower than gross output PPPs and are even close to the official exchange rate. The cross-industry differences in value added PPP are larger than for gross output. This is to be expected from the double deflation method, where small differences between input and output PPPs tend to be magnified, due to the low share of value added in gross output.

COMPARATIVE VALUE ADDED AND LABOR PRODUCTIVITY BY BRANCH

In Table 4, we compare value added and employment by manufacturing branch, using the Fisher value added PPPs to put value added in comparative prices. Total value added of the German census data was 24 percent higher than the U.K. data, and employment about 16 percent.

In both countries the branches of iron and steel, engineering, and non-ferrous metals combined comprised the largest sector. The share in Germany made up 42 percent of value added and 41 percent of employment. In the United Kingdom the shares were 33 and 34 percent, respectively. Textiles, leather, and clothing came in second place amounting to 16 percent of value added and 23 percent of employment in Germany versus 21 percent and 32 percent in the United Kingdom. Note that in both countries labor productivity levels were rather low in textiles and just average in the metal industry. On the other hand, both food and chemicals showed high productivity, a sign of great capital intensity. These industries amounted to 23 percent of value added in Germany and employed 14 percent of the labor force, compared to 24.5 and 14 percent, respectively, in the United Kingdom. Output characteristics thus suggest that Germany produced relatively more capital-intensive and intermediate goods (metals, chemicals), while in Britain industries produced consumption goods (textiles, clothing, food, paper and printing).

Combining the information on comparative levels of value added in the previous paragraph with our productivity estimates presented in Table 1, we can compare our results with the productivity comparison of

TABLE 4
THE STRUCTURE OF VALUE ADDED AND EMPLOYMENT IN MANUFACTURING: UNITED KINGDOM AND GERMANY, 1935–1936

	Value Added		Germany as % of United Kingdom ^b	Employment ^a		Germany as % of United Kingdom
	Germany (1,000 RM)	United Kingdom (1,000 £)		Germany	United Kingdom	
Textile trades	2,831,552	157,503	65.5	906,187	1,054,860	85.9
Leather trades	402,611	10,668	86.6	92,946	50,533	183.9
Clothing trades	1,075,729	80,995	61.0	350,110	535,886	65.3
Iron and steel trades	4,114,457	116,508	308.7	950,573	539,270	176.3
Engineering, shipbuilding, and vehicles trades	6,177,892	249,322	133.1	1,385,384	1,104,363	125.4
Nonferrous metals trades	650,416	29,947	110.1	129,280	122,097	105.9
Food, drink, and tobacco trades	3,543,298	201,515	82.1	549,244	520,649	105.5
Chemical and allied trades	2,419,791	88,486	184.4	285,151	194,011	147.0
Miscellaneous trades	1,254,199	43,703	140.2	270,713	182,619	148.2
Clay and building materials trades	1,178,260	54,086	150.5	355,374	249,438	142.5
Paper, printing, and stationery trades	1,509,823	111,661	128.2	371,910	408,967	90.9
Timber trades	952,451	37,268	149.3	323,009	194,894	165.7
Total manufacturing	26,110,479	1,181,662	123.6	5,969,881	5,157,587	115.7

^a Numbers of people employed.

^b Ratio of value added in national currencies converted with (Fisher) value added PPPs from Table 3.

Source: Data are from Fremdling, de Jong, and Timmer, "Censuses Compared." www.ggdgc.net

Broadberry and Fremdling, who reworked Rostas's comparison based on the physical quantities in the German *Statistisches Jahrbuch* and the British *Census of Production* of 1935.⁴⁴ Whereas we were able to draw nearly on complete sets for all manufacturing industries in the censuses, Broadberry and Fremdling's choice was dictated by the availability of some 20 pairs of industries in the published statistics for both countries. Surprisingly, the outcome at the aggregate level is very close to our double deflated result.⁴⁵ Although the choice of a method does not affect the results at the aggregate level, it does do so for individual industries, where large differences can be found. Our double deflated results yield lower German productivity levels in textiles and in the engineering branch, but higher estimates for nonferrous metals, clay and building materials, iron and steel, and especially food. The differences emerge clearly from a comparison with the physical quantity estimates of Broadberry and Fremdling (Table 5).

In textiles, leather, and clothing, Broadberry and Fremdling's estimates are higher. We uncovered significant differences for cotton spinning and doubling, because the Germans used low-value waste materials and spun rayon in the production process.⁴⁶ Furthermore, Broadberry and Fremdling did not include the important wool industry. Our present estimate reveals a clear British productivity lead in the wool industry, which lowered German comparative productivity for textiles as a whole. In clothing our estimate for German productivity is substantially below Broadberry and Fremdling's. One reason is that clothing includes shoemaking, where the German comparative productivity level comes out quite low.

In engineering, shipbuilding, and vehicles our method ranks Germany close to a par with Britain (its index is just above 106, see Table 1). Broadberry and Fremdling give two figures separately for particular industries of this branch (see Table 5): For motor vehicles we found Germany on a par with Britain (its index is just 98) versus the much higher score (141) given by Broadberry and Fremdling. In electrical and mechanical engineering (machinery), however, we calculated 126 compared with 112 by them. Our high score is mainly due to the extraordinary

⁴⁴ Rostas, *Comparative Productivity*.

⁴⁵ Broadberry and Fremdling calculated physical output per worker and arrived at an unweighted German average of 101.9 percent of the U.K. level. The ratio rises to 113.7 when employment weights of the United Kingdom are used and remains about the same (102.1) when German weights are applied. The geometric mean of the two weighted ratios can be calculated at 108. In *The Productivity Race* Broadberry combined these data for certain industrial branches. For aggregation at the industry level he used either German or British employment weights and a geometric mean (in other words the Fisher index). For manufacturing as a whole, however, he opted for an unweighted ratio of 102. Broadberry, *Productivity Race*, pp. 22–31.

⁴⁶ Höschle, *deutsche Textilindustrie*, pp. 42–53, 114–28; Müller, *Manager*, pp. 38–43.

TABLE 5
LABOR PRODUCTIVITY BY INDUSTRY: UNITED KINGDOM AND GERMANY,
1935–1936
(Germany as Percentage of United Kingdom)

	Present Estimate	Broadberry / Fremdling
Cotton spinning	77	100
Cotton weaving	73	69
Rayon	106	109
Jute	97	116
Leather tanning and dressing	36	99
Boots and shoes	58	121
Blast furnaces, iron foundries and steelworks	175	116
Electrical and mechanical engineering	126	112
Motor vehicles	98	141
Nonferrous / Zinc	104	85
Beet sugar	71	33
Margarine	78	52
Brewing	94	62
Tobacco	20	26
Soap	124	110
Seedcrushing	128	50
Rubber	117	112
Coke	108	174
Cement	91	87

Sources: Data are from Fremdling, de Jong, and Timmer, "Censuses Compared." www.ggdc.net; and Broadberry and Fremdling, "Comparative Productivity," p. 405.

performance of electrical engineering alone where our index reached 155. According to our findings for the entire branch, Britain performed better than has commonly been assumed. Alan Booth recently reached a similar conclusion when he assessed British comparative performance in manufacturing and engineering in particular.⁴⁷ Our estimates allow a more detailed picture of particular engineering industries. German productivity was especially high in electrical engineering, less elevated in mechanical engineering (110), and on a par with or even lower than the United Kingdom's in the aircraft, shipbuilding, and railway equipment industries.

The food industry reveals the biggest differences between the two studies. Our present estimate for the food industry ranks Germany at 78 percent of the U.K. level (see Table 1). Broadberry and Fremdling calculated a much lower level of 41 percent, being the weighted average of four industries: beet sugar, margarine, brewing, and tobacco. We believe that this gap has to be explained by a number of factors. First, in some industries (notably sugar) we calculated average employment for

⁴⁷ Booth, "Broadberry-Crafts View," p. 737.

the entire year, and did not rely on just a seasonal employment peak. Second, there are large differences in coverage. The present estimate includes all food industries (grain milling, cocoa and sugar confectionary, preserved foods, and so on), some of which had somewhat lower levels of productivity in the United Kingdom. Third, we were able to adjust for the relatively high German prices for intermediate inputs, which were brought on by tariffs and Germany's agricultural policy. The result was a less pronounced advantage for the United Kingdom than we would have obtained from physical estimates. Chemical industries show similar patterns. Adjustment for relatively high input prices in Germany resulted in higher levels of value added and thus labor productivity. The clearest example here was seedcrushing, where we got completely reversed productivity levels. In our opinion, the results from double deflation here are far superior to any physical estimation and to single deflation, because differences in relative intermediate input prices mattered a lot in many industries.

CONCLUSIONS

In this study, we presented new estimates of relative productivity performance in manufacturing industries of the United Kingdom and Germany for the years 1935 and 1936 respectively. Using a consistent method, we tried to build a conclusive edifice of comparative Anglo-German levels of value added and labor productivity. This comparison is based on single and double deflation techniques. Four major conclusions can be drawn. First, it seems that on the aggregate level the outcome is unaffected by choice of method. Using single deflation we find that Germany led the United Kingdom in labor productivity by 5 percent, and by 7 percent using our preferred method of double deflation. Both estimates are close to the previous finding of Broadberry and Fremdling, who used a quantity approach and a smaller set of industries.

Second, on the disaggregated level of specific branches, double deflation makes a difference but its advantages are clear. We find a much lower German performance in textiles and engineering branches than Broadberry and Fremdling, but higher levels for nonferrous metal, clay and building materials, iron and steel, and especially food. Our double deflated results seem more plausible because they adjust for big differences in prices of intermediate inputs. The price differences can be tracked back to Germany's striving for autarky, which led to distorted prices and production structures in the 1930s.

Third, our archival evidence invalidates Hoffmann's reconstruction of German national accounts for 1850–1959, which relies on the mis-

leading and incomplete information in the published version of the census. As a result Angus Maddison's data will be affected too because the Hoffmann time series underlie his country entries for Germany.⁴⁸ Specifically, these new benchmark estimates can be used for backward extrapolations to shed new light on the comparative performance of the United Kingdom and Germany before World War I and they may contribute to improvements on Hoffmann's time series for German industrial output.⁴⁹

Finally, we have shown that the use of double deflation techniques is not only superior in theory, but also feasible in practice. More attempts should be made to apply this method to other sectors and other countries in order to improve benchmark comparisons of productivity performance.

Appendix 1: Comparing the British and German Censuses

Because small companies were treated differently in each country's census, comparative productivity levels for Germany might be biased downwards. The reason is that the German census includes most of the group of firms employing five to ten employees, whereas the British does not. The effect could be large if the level of productivity of small firms was substantially lower than for total manufacturing. Fortunately, the U.K. census gives information on productivity levels by firm size. We calculated that the smallest firms in the British census (between 11 and 24 workers) averaged about 90 percent of the productivity of manufacturing as a whole. We know that the share of the total manufacturing labor force in the firm-group between one to ten workers was about 10 percent in the United Kingdom.⁵⁰ Now let us assume that the 5–10 group (which is included in the German census but not in the British) had a productivity level of 80 percent of the total industry-average in the United Kingdom. Including this hypothetical group in the U.K. census, would result in a downward adjustment of the productivity level for total British manufacturing of maybe 2 percent, but certainly not more. Or stated from the German point of view, the downward bias of average productivity for German manufacturing as a whole vis-à-vis the United Kingdom was 2 percent at maximum.

⁴⁸ Maddison, *World Economy*.

⁴⁹ Albrecht Ritschl recently corrected the Hoffmann-index on German industrial output for the period 1913–1938 by imputing a new series for metal processing. This adjustment yields figures indicating a less marked growth during the interwar period. If, however, Ritschl's time series is extrapolated backwards from our benchmark 1935/36 it yields a very high productivity level for Germany vis-à-vis Britain for the period before World War I, which is far above the benchmark estimates reported by Broadberry and Burhop. A first step in reconciling this contradictory evidence is to produce a completely new time series on industrial output, as suggested by Ritschl. This means making further use of the unpublished 1936-census data and additional archival sources available at the Federal Archive Berlin-Lichterfelde. See the discussion in Ritschl, "Spurious Growth"; Burhop and Wolff, "Compromise Estimate"; and Broadberry and Burhop, "Comparative Productivity."

⁵⁰ Rostas, *Comparative Productivity*, p. 25.

APPENDIX TABLE 1
POTENTIAL BIAS IN MEASURED PRODUCTIVITY LEVELS OF THE
UNITED KINGDOM (1935) AND GERMANY (1936)

	United Kingdom	Germany	Percentage Bias in Favor of Germany
Exemption limits	Less than 10	Less than 5	minus 2
Hours worked	47 hours	45 hours	minus 4
Repair in value added	Excluded	Included	plus 4
Year of comparison	1935	1936	plus 3
Net effect			plus 1

Sources: Authors' estimations from Board of Trade, *Final Report*; Reichsamt, *Die deutsche Industrie*; BA R3102; see the text and Appendix 1.

Generally, the concepts of gross output, intermediate input, and value added (or net output) used in both censuses are the same. Net output represents the value added through the manufacturing process, which is the sum of wages, salaries, rent, rates and taxes, depreciation of plant and machinery, advertisement and selling expenses, and profits. This is equal to (gross) census value added at market prices. The only difference is the treatment of repair and maintenance of own capital goods. In the British census, firms had to include the materials used for the repair and maintenance of their own buildings and machinery in the intermediate inputs, whereas in the German statistics they were excluded. From the estimations in the official publication the value of repair and maintenance for total manufacturing can be calculated at RM1,000–1,500 million, which is about 4 percent of total value added.⁵¹ Because these repair and maintenance costs are included in German value added, productivity for German manufacturing as a whole is raised by 4 percent.

The census years for the comparison between the United Kingdom and Germany differ by one year. Apart from business cycle and capacity utilization effects, we also have to take account of the long-term rise in productivity levels in both economies. To adjust for this we made use of the existing productivity time series estimates and calculated the average movement in productivity levels in both countries between 1935 and 1936.⁵² We arrived at a 3 percent bias in favor of Germany, due to the fact that we measured German productivity of 1936 instead of 1935.

Finally, an adjustment could be made for differences in hours worked. Ideally, one would measure labor productivity as value added per hour worked, but detailed industry-level estimates of hours worked are not available. According to various sources the average working week in the United Kingdom was 47 hours per week compared to 45 in Germany.⁵³ This means that we in fact overstate British labor productivity by 4 percent in our comparison, if we express labor productivity in hours worked.

The net effect of these biases on productivity for manufacturing as a whole is summarized in Appendix Table 1.

Adjustments for Duties and Taxes

In general, excise duties and consumer taxes are not included in the value added. For some industries in the census reports, however, duties are included in the gross

⁵¹ Reichsamt, *Die deutsche Industrie*, pp. 18, 37.

⁵² See Broadberry, *Productivity Race*, p. 44.

⁵³ Rostas, "Industrial Production," p. 46.

APPENDIX TABLE 2
GROSS PRODUCTION VALUE ADJUSTED FOR DUTIES AND TAXES,
UNITED KINGDOM (1935) AND GERMANY (1936)

	United Kingdom, 1935 (1,000 £)	Germany, 1936 (1,000 RM)
Total gross production value in the census	2,837,124	56,868,856
Minus duties/excises on:		
Silk	2,091	
Drugs	740	
Matches	2,110	
Margarine		232,321
Edible oils		119,526
Sugar	2,500	
Beer	55,300	
Aerated waters	700	
Tobacco	79,327	
Printing	70	
Adjusted gross production value	2,694,286	56,517,009

Sources: Authors' calculations from Board of Trade, *Final Report*; Reichsamt, *Die deutsche Industrie*; BA R3102; see the text and Appendix 1.

production value. To put both countries on the same footing, we deducted excises from the gross production value. In the United Kingdom we subtracted excises on silk, drugs, matches, printing, aerated waters, tobacco, sugar, and beer, according to the values mentioned in the General Report of the census. A special case here is the duty on tobacco, which was not paid for by firms on sales or gross output but on imports into the United Kingdom. We estimated this duty, including subtracted drawbacks on tobacco exports from the United Kingdom, at £79,327,000 and adjusted both intermediate inputs and gross output by this number. A similar duty was charged in the petroleum industry but we could not calculate the total amount because firms had been requested to include this in their statement of the cost of materials. In total, we deducted £142,780,000 from the U.K. gross production value. Therefore the gross production value in our study is £2,694.3 million instead of £2,837.1 million in the census. In the case of Britain, this adjustment had no effect on the net production value whatsoever. In the case of Germany, however, the gross production value as well as the value added derived from the archival sources included taxes for certain industries, namely for margarine and edible oils. The figures were adjusted by RM351.8 million.

Appendix 2: Double Deflation

As a first step, unit values (uv) are derived by dividing ex-factory output values (o) by produced quantities (q) for each product i in each country

$$uv_i = \frac{o_i}{q_i} \quad (A1)$$

The unit value can be considered as an average price, averaged throughout the year for all producers and across a group of similar products, *sold in domestic as well as for-*

eign markets, thus including exports. Subsequently, in a bilateral comparison, broadly defined products with similar characteristics are matched, for example boilers, cigarettes, margarine, and car tires. For each matched product, the ratio of the unit values in both countries is taken. This unit value ratio (*UVR*) is given by

$$UVR_i^{BA} = \frac{uv_i^B}{uv_i^A} \quad (A2)$$

A and *B* are the countries being compared, with *A* taken as the base country. The product *UVR* indicates the relative producer price of the matched product in the two countries. Product *UVRs* need to be aggregated to derive converters for gross output for individual industries or for the aggregate sector. (Henceforth we shall label these converters *GO-PPP* with a superscript for the country and subscript if a particular industry is concerned.) This can be done in a single step from product to aggregate manufacturing, but also in multiple steps. Because only a selected number of products are matched, the *UVRs* are then weighted several times, first according to their output share in the individual industry, then according to the industry's share in the branch of manufacturing and finally according to the branch share in manufacturing as a whole. As a result, the aggregate *GO-PPP* better reflects the actual share of each underlying product item for which *UVRs* are available in total output. The *GO-PPP* for industry *j* based on the industry-of-origin approach is given by

$$GO-PPP_j^{BA} = \sum_{i=1}^{I_{j,GO}} w_{ij} UVR_{ij}^{BA} \quad (A3)$$

with $i = 1, \dots, I_{j,GO}$ the matched output products in industry *j*; $w_{ij} = o_{ij} / o_j$ the output share of the *i*th commodity in industry *j*; and $o_j = \sum_{i=1}^{I_{j,GO}} o_{ij}$ the total matched value of output in industry *j*. In bilateral comparisons the weights of either the base country (*A*) or the other country (*B*) can be used, which provide a Laspeyres and a Paasche type PPP respectively. The Laspeyres gross output PPP, $GO-PPP_j^{BA(A)}$, is given by

$$GO-PPP_j^{BA(A)} = \sum_{i=1}^{I_{j,GO}} w_{ij}^{A(A)} UVR_{ij}^{BA} \quad (A4)$$

And the Paasche by

$$GO-PPP_j^{BA(B)} = \sum_{i=1}^{I_{j,GO}} w_{ij}^{A(B)} UVR_{ij}^{BA} \quad (A5)$$

with $w_{ij}^{A(A)}$ the output weights of product *i* in base country prices and quantities, and $w_{ij}^{A(B)}$ the quantity weights of the other country valued at base country prices. The geometric average of the Laspeyres and Paasche indices, the Fisher index, is often used when a single currency conversion factor is required. PPPs for intermediate input

can be derived in a similar way. The Laspeyres intermediate input PPP, $II - PPP_j^{BA(A)}$, is given by

$$II - PPP_j^{BA(A)} = \sum_{i=1}^{I_{j,II}} v_{ij}^{A(A)} UVR_{ij}^{BA} \quad (A6)$$

And the Paasche by

$$II - PPP_j^{BA(B)} = \sum_{i=1}^{I_{j,II}} v_{ij}^{A(B)} UVR_{ij}^{BA} \quad (A7)$$

with $i = 1, \dots, I_{j,II}$ the matched intermediate inputs in industry j with $v_{ij}^{A(A)}$ the intermediate input weights of product i in base country prices and quantities, and $v_{ij}^{A(B)}$ the quantity weights of the other country valued at base country prices. Both the output and the input weights are calculated directly from the census data.

From both output and intermediate input PPPs we can now calculate the double deflated PPPs. Let GO_j^A and II_j^A denote respectively the value of gross output and intermediate input of industry j in country A at national prices, and similarly for B . The Laspeyres value added PPP, $VA - PPP_j^{BA(A)}$, is then given by

$$VA - PPP_j^{BA(A)} = \frac{GO_j^A \times GO - PPP_j^{BA(A)} - II_j^A \times II - PPP_j^{BA(A)}}{GO_j^A - II_j^A} \quad (A8)$$

And the Paasche value added PPP, $VA - PPP_j^{BA(B)}$, is given by

$$VA - PPP_j^{BA(B)} = \frac{GO_j^B - II_j^B}{GO_j^B / GO - PPP_j^{BA(B)} - II_j^B / II - PPP_j^{BA(B)}} \quad (A9)$$

It can easily be seen that in the case of identical gross output and intermediate input PPPs, the value added PPP is the same as the gross output PPP. But if not, the difference between the two depends on the share of intermediate inputs in gross output and the difference between the GO - and II -PPP.

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