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A TALE OF TWO TAILS: ESTABLISHMENT SIZE AND LABOUR PRODUCTIVITY IN UNITED STATES AND GERMAN MANUFACTURING AT THE START OF THE TWENTIETH CENTURY

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This paper studies the importance of establishment size for the German/US labour-productivity gap in manufacturing at the start of the twentieth century. First, we show that the left tail of the employment distribution by establishment size was larger in Germany than in the USA. Second, using US state data for 1909, we find a positive correlation between establishment size and labour productivity. Third, imposing the coefficients of these estimates on establishment-size differences between Germany and the USA, we calculate that a redistribution of German employment to larger establishments, as in the USA, reduces the labour-productivity gap by about 25 per cent.

JEL categories: L11, L60, N61, N63, O14

Keywords: establishment size, Germany, labour productivity, pre-1913, United States

INTRODUCTION

Germany's rapid economic development from the late nineteenth century onwards has traditionally been described as an example of catch-up growth.¹ In particular the rapid transformations in the new, science-based industries of the second industrial revolution, such as engineering, chemical production, and metal manufacturing, have received broad attention.² Nevertheless, the existing quantitative evidence suggests that before WWI German manufacturing performed at only half the labour-productivity level of the global labour-productivity leader,

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1 Gerschenkron, *Economic backwardness*; Landes, *The unbound Prometheus*.

2 Braun, *The German economy*.

the USA.³ The UK trailed the USA at a roughly similar distance, and the literature has identified several reasons for this large transatlantic labour-productivity gap.

First, it has been argued that low relative labour costs in Europe discouraged the substitution of machinery for skilled labour, which in turn constrained the adoption of labour-productivity enhancing technology.⁴ Second, whereas the USA relied on high levels of human capital accumulation through formal education aimed at managerial and researcher skills, Germany and the UK relied on shop floor workers that were trained under an apprenticeship system.⁵ Third, it has been suggested that the small scale of European production negatively affected labour productivity. Large-scale production and standardisation was limited, because producers in Europe faced a smaller domestic market characterised by a demand for customised goods.⁶

As much of the evidence is based on the case of Britain, the question remains whether the British constraints to labour-productivity growth applied to Germany also. This paper addresses part of that question by studying the importance of the scale of production for the German/US manufacturing labour-productivity gap at the start of the twentieth century. In particular, we build on the notion that the technologies of the Second Industrial Revolution typically involved mass production techniques with high fixed costs but low variable costs. Large establishments (factories or plants) obtained labour-productivity benefits through economies of scale. The US adopted standardisation and high-throughput production technology more widely than the European countries. European markets were smaller and typically specialised in customised production.⁷ This suggests that US manufacturing enjoyed a labour-productivity advantage over European countries. Germany's inability to catch-up with US labour-productivity may thus have originated from market conditions that prevented less efficient firms from losing market share and profit to the more efficient ones.⁸

Average establishment size in German manufacturing was indeed smaller than in the USA, as Kinghorn and Nye show for the pre-WWI period.⁹ Also, the employment share working in large-scale establishments (>50 workers) was substantially lower in Germany than in the USA. This is only part of the story, however. In times of rapid technological change, elements of backwardness and modernity are likely to coexist as the replacement of the old stock of production technology proceeds stepwise. Therefore, rather than looking at average establishment size in industries or at only the employment share of large plants, it may warrant to study the full employment distribution by establishment size. If

3 Broadberry and Irwin, 'Labor productivity'; Broadberry and Burhop, 'Comparative productivity'; Ritschl, 'The Anglo-German productivity puzzle'; Broadberry and Burhop, 'Resolving'.

4 Habakkuk, *American and British technology*; David, *Technical choice*; Temin, 'Labour scarcity'; Field, 'On the unimportance'.

5 Broadberry, *The productivity race*, p. 127.

6 Rostas, 'Industrial production'; Chandler, *Scale and scope*; Landes, *The unbound Prometheus*; Broadberry, 'Technological leadership'.

7 Broadberry, 'Technological leadership'.

8 In a way that is not too different from the mechanisms described in Melitz (2003).

9 Kinghorn and Nye, 'The scale of production'.

new technology of the Second Industrial Revolution was indeed embodied in large-scale production, the mix of technologies used in manufacturing can be observed in the distribution of employment over establishment size; the left tail captures traditional technologies and the right tail modern technologies.

The idea that establishment size can be seen as a proxy for technology has been put forward in this context earlier by Hannah, who observed that giant production units ($>1,000$ workers) were particularly representative for 'modern' industries.¹⁰ Hannah shows that such modern elements were widely present in Germany before WWI with the number of giant factories not too different from the USA. This can be understood, he argues, as a result of an integrated European market in the pre-WWI era realised by low transport costs and high population densities; even though domestic markets in Europe were relatively small, the larger European market may have encouraged the development of large-scale production. Combining Hannah's giant factories with Kinghorn and Nye's conclusion that the overall average establishment size in German manufacturing was smaller than in the USA, it is clear that German industries featured both large (modern) production units and small (traditional) establishments. Aggregate labour productivity in industries is then determined by the balance between the weight in the left and right tails of the employment distribution by establishment size; Hannah suggests it might have been the bulk of small workshops that drove Germany's low overall labour productivity.¹¹

This paper adds to the literature in two ways. First, we present a new German/US benchmark comparison of labour productivity in manufacturing for 1909. This is necessary because until now direct German/US comparisons were not available. If we want to know to what extent differences in establishment size contributed to the labour-productivity gap between German and US manufacturing, that gap needs to be reliably estimated first. Second, we link our new labour-productivity estimates to data on the scale of production in Germany and the USA. In analysing the labour-productivity effect of cross-country variation in establishment size before WWI, the literature has focused primarily on differences in average establishment size.¹² In contrast, we consider the labour-productivity effect of differences over the full range of the employment distribution by establishment size. This allows us to study the importance of the left and right tails of the employment distribution for overall labour-productivity levels in manufacturing industries.

THE GERMAN/US MANUFACTURING LABOUR PRODUCTIVITY GAP IN 1909

While the comparison between Germany and the USA has not been made for 1909, the literature does provide German/UK and USA/UK comparisons for pre-WWI

10 Hannah, 'Logistics', pp. 68–9.

11 Hannah, 'Logistics'.

12 Broadberry and Fremdling, 'Comparative productivity'.

and interwar years. These can be used to construct a German/US comparison. Such an indirect estimate is problematic, however, because the size of the gap between Germany and the UK has been disputed. Steven Broadberry and Carsten Burhop as well as Albrecht Ritschl have presented German/UK benchmarks for 1907, reporting a productivity ratio in manufacturing of 1.08 and 1.28, respectively.¹³ Contingent on the choice between these benchmarks, Broadberry and Irwin's estimate of a 2:1 American lead over Britain in 1909/10 implies a German/US productivity ratio of either 0.54 (via Broadberry and Burhop) or 0.63 (via Ritschl).¹⁴ It is difficult to study the contribution of establishment-size differences on the labour-productivity gap when the size of the latter is disputed. Therefore, we present a new, direct benchmark estimate for German/US comparative labour-productivity levels in 1909.

We base the benchmark on production data published by the statistical offices of Germany and the USA. The analysis for the USA is based on the *Thirteenth Census of the United States* published by the US Bureau of Commerce. Collecting data to calculate labour productivity for pre-WWI Germany was more challenging, because the first German census of manufacturing was not conducted until 1936. Consequently, we use a combination of other sources for the pre-WWI period. We rely mainly on information obtained from the *Vierteljahrshefte zur Statistik des deutschen Reichs* [quarterly statistics of the German Empire], a publication of the Kaiserlichen Statistischen Amte [Imperial Statistical Office]. In the quarterly statistics of 1913 the results of industrial surveys are published for the years between 1907 and 1911. Unfortunately, several manufacturing industries are not included in the surveys. We retrieved data on some of these industries from other publications of the Imperial Statistical Office, that is, the *Statistisches Jahrbuch für das deutsche Reich* [statistical of the German Empire] of 1907–12, the *Industrielle Produktionsstatistik* [industrial production statistics] of 1927, 1928, and 1934, and publications of the *Ausschuss zur Untersuchung der Erzeugungs- und Absatzbedingungen der deutschen Wirtschaft* [The commission for the study of production and market conditions in the German economy].¹⁵ Lastly, we use employment weights obtained from the *Gewerbliche Betriebsstatistik* (workplace census), published as part of the *Berufs- und Betriebszählung* [occupational and workplace census] of 1907, to aggregate from the industry level to total manufacturing.

Our benchmark compares levels of gross output per employee by industries between countries using an industry-specific conversion factor or purchasing power

13 Broadberry and Burhop, 'Comparative productivity', p. 321; Ritschl, 'The Anglo-German productivity puzzle', p. 594; Broadberry and Burhop, 'Resolving', p. 932. For an overview of the debate, see Veenstra, 'Output growth'. In contrast to previous contributions to this debate, Veenstra provides a measure of uncertainty in his estimates using the confidence intervals obtained with time series analysis. The benchmark estimate of Broadberry and Burhop falls within the upper and lower confidence limit around Veenstra's point estimate, while Ritschl's benchmark does not.

14 US/UK. comparative labour productivity is taken from Broadberry and Irwin, 'Labor productivity'.

15 For more detail on the sources used here, see Veenstra, *Missed opportunities?*. Burhop, 'The level of labour productivity', also exploits many of these sources for estimating German labour-productivity levels in 1913. Furthermore, Burhop discusses firm size and sample selection biases in the German data.

parity (henceforth, PPP) to convert German output values expressed in gold marks into US dollars.¹⁶ The Fisher PPPs listed in Table 1 differ markedly between manufacturing industries. It follows that the official exchange rate, which in 1909 stood at a 4.20 ratio of gold marks to US dollars, functions poorly for the purpose of converting output at the industry level.¹⁷ On the total-manufacturing level, however, the 1909 Fisher PPP approaches the official exchange rate closely, which signals that the latter reflects fairly accurately the average (but not industry level) price ratio between Germany and the USA. Looking at the industry PPPs presented in Table 1, the Laspeyres and Paasche PPPs vary substantially in several industries. This is an indication of structural differences between the countries under comparison. The difference between the Laspeyres and Paasche PPPs stems from the use of, respectively, base-country (USA) or non-base country (German) weights for the process of aggregation and variation between the two is evidence of dissimilar production structures.

Our output-based PPP for manufacturing can be compared with an indirect expenditure PPP calculated as the ratio between the German/UK expenditure PPP for 1905 (20.62 gold marks per pound) and the USA/UK expenditure PPP for 1905–12 (6.48 US dollar per pound).¹⁸ This indirect expenditure PPP points at a German/US price ratio of 3.18 gold marks per US dollar, which is lower than our output-based manufacturing PPP.

The latter should be preferred over the former for two reasons. First, using the indirect expenditure PPP to convert German nominal values in US dollar would raise Germany's comparative performance from 61 to 75 per cent the level of the USA. This suggests an implausibly strong German performance that cannot be reconciled with the literature. Second, from a methodological point of view there are various reasons to expect a discrepancy between our direct output PPP for manufacturing and an indirect expenditure PPP. To start with, any indirect estimate is prone to errors due to intransitivity. Furthermore, and more importantly, the expenditure PPP compares price levels at the total economy level, while our output PPP is based on manufacturing. Only when the output PPP covers manufacturing as well as mining, agriculture and services, and assuming the national accounting identity that GDP calculated from the expenditure and output side should be equal, may we reasonably expect expenditure and output PPPs to reconcile.¹⁹

16 For more detail on the methodology applied here, see Veenstra, *Missed opportunities?*

17 Svernilson, *Growth and Stagnation*, p. 318.

18 The German/UK expenditure PPP for 1905 is taken from Broadberry and Burhop, 'Real wages', p. 405; The USA/UK expenditure PPP is taken from Broadberry and Irwin, 'Labor productivity', p. 261.

19 In addition, the German data for 1909 is limited to a sample of manufacturing industries. Using a German/US benchmark for 1936/35 (see Veenstra, *Missed opportunities?*, p. 192), we can compare the PPP for our sample of industries with the PPP based on all manufacturing industries. This reveals that the latter deviates more from the exchange rate than the former. If we calculate the factor by which the total-manufacturing PPP deviates more from the exchange rate than the sample-based PPP and correct our 1909 PPP accordingly, we get an 'adjusted' price ratio of 3.39 gold marks per US dollar. This is closer to the indirect expenditure PPP, but – for the reasons mentioned above – this may be coincidental more than anything else.

Table 1. PPPs and comparative labour productivity in German and US manufacturing, 1909

Industry	PPP German gold marks/US dollar			Comparative labour productivity (US = 100)
	Laspeyres	Paasche	Fisher	
Manufacturing	4.33	3.49	3.89	61
Food and kindred products	4.19	2.87	3.47	55
<i>Sugar</i>				58
<i>Brewing</i>				56
Tobacco manufactures [†]	4.33	3.49	3.89	30
<i>Tobacco</i>				30
Textile mill products	2.85	2.85	2.85	90
<i>Cotton (spinning only)</i>				92
<i>Silk</i>				133
<i>Woollen</i>				84
<i>Linen</i>				75
<i>Jute</i>				142
Paper and allied products	4.59	4.53	4.56	53
<i>Paper, cardboard and pulp</i>				53
Chemical and allied products	3.64	2.83	3.21	80
<i>Sulfuric acid</i>				130
<i>Coal tar products</i>				90
<i>Miscellaneous chemicals</i>				55
Petroleum and coal products	6.63	6.05	6.33	42
<i>Petroleum refining</i>				26
<i>Coke and by-products</i>				94
Rubber products	7.71	7.71	7.71	50
<i>Tires</i>				50
Leather and leather products	4.86	5.42	5.13	66
<i>Leather tanning and dressing</i>				66
Stone, clay, and glass products	4.13	4.12	4.12	51
<i>Cement</i>				61
<i>Glass</i>				52
Primary metal products	3.58	3.22	3.39	65
<i>Iron and steel</i>				81
<i>Nonferrous metals</i>				31
Transportation equipment	4.82	5.03	4.92	30
<i>Motor vehicles</i>				30

[†] No price information available for this industry; assigned PPP of total manufacturing. See Appendix II for the robustness of the PPPs. *Sources:* see text.

Furthermore, the expenditure PPPs rely on wholesale prices, while our output-based PPP for manufacturing is based exclusively on factory-gate prices.

The conversion of industrial output with the PPPs enables us to make a comparison of German and US labour-productivity levels in 1909. Our new estimates of comparative labour productivity are listed in the last column of Table 1. The results of the benchmark comparison for total manufacturing align

with the traditional view on the 'productivity race', with the USA enjoying a commanding lead over Europe throughout the first half of the twentieth century.²⁰ Nevertheless, whereas German manufacturing lagged far behind the USA on average, comparative performance across manufacturing industries varied considerably. Many industries failed to keep up with the USA and performed at half, or even less, the level of their American counterparts. At the low end are tobacco manufacturing and the transportation-equipment industry. Paper production and leather performed somewhat better but still lagged far behind. Other industries, however, did manage to keep up with the USA. This was a small group including textiles, chemicals, and some sub-industries in primary metals (viz. the iron and steel industries, but not nonferrous metals production) as well as petroleum and coal (viz. coke manufacturing, but not petroleum refining). In short, the range of German industrial performance relative to the USA was large.

There are some, but not many industry studies to compare our results with. We can contrast our findings with Robert Allen's work on the iron and steel industry in 1907/09.²¹ Allen reports a German labour-productivity level 84 per cent of the USA.²² We find a German performance in primary metals 67 per cent of the USA. In addition to iron and steel, however, our primary metals industry includes also nonferrous metals production. Excluding nonferrous metals from the comparison leads to a German labour-productivity level 81 per cent of the USA, that is, very close to Allen's findings. We can also contrast our results with an indirect German/US comparison based on Broadberry's German/UK and US/UK benchmarks.²³ Such an indirect comparison is possible for motor vehicles, sugar, brewing and malting, and cement production, which are classified in our benchmark as sub-industries of, respectively, the transportations equipment, food and kindred, and stone, clay, and glass industries. The results for cement are almost identical, but for the others our findings can be up to 30 per cent higher or lower than the indirect comparison. These differences can be ascribed partly to the use of methodology. Whereas Broadberry relied on a quantity comparison, we apply the preferred technique of converting monetary output values in a common currency using PPPs.

When first examined, the results of the benchmark comparison can be seen to support Hannah's suggestion that the scale of production may have been an important determinant of labour-productivity levels in Germany.²⁴ A common characteristic shared by the industries that managed to approach US performance levels was that they produced mainly basic or standard goods. A large part of output in primary metals was processed further in the fabricated-metals, (electrical) machinery or transportation-equipment industries. The textile industries studied

20 Broadberry, *The productivity race*.

21 Allen, 'International competition'.

22 Allen, 'International competition' p. 919.

23 Broadberry, *The productivity race*.

24 Hannah, 'Logistics'.

for 1909 concern spinning activities producing yarn and thread, which was subsequently used in weaving or apparel industries. The chemical products included in the comparison, in particular sulfuric acid and potassium compounds (miscellaneous chemicals), formed the intermediate inputs needed for the production of fertilisers. Conversely, many of the industries facing a particularly large gap compared with the USA were involved in the production of predominantly consumer goods; the food and drink and transportation-equipment industries being prime examples. This may suggest that industries producing basic goods performed well, because they did not face the heterogeneous demand on consumer markets and were therefore better positioned to profit from economies of scale.

THE SIZE OF ESTABLISHMENTS IN GERMAN AND US MANUFACTURING

A relatively less-developed German system of large-scale production provides a possible explanation of the performance gap, but the supporting evidence is tentative so far. The hypothesis relies on two assumptions, namely that the size of establishments was relatively large in the strong performing German industries and that establishment size was positively related to labour productivity. But do these assumptions hold? In this section we study the validity of the first assumption by looking at differences in establishment size between German and US manufacturing industries.

To see if the pattern of comparative performance is mirrored by differences in establishment size between Germany and the USA, we explore data provided by the German workplace census of 1907 and by the US *Thirteenth Census of Manufactures* of 1909. Both sources report the distribution of establishments and of employees over various establishment-size classes. Kinghorn and Nye have previously studied the distribution of employment over establishment size, with the difference that they did not link the data on establishment size to labour productivity.²⁵ As we do take that next step in this study, the establishment-size data are classified according to the aggregation scheme of our new labour-productivity benchmark, and the coverage of industries consequently differs from the work of Kinghorn and Nye.

The US census of manufactures reports the number of manufacturing establishments and the number of wage earners per establishment-size class. There are nine classes, ranging from establishments with zero wage earners to those with more than 1,000. The census includes all establishments that annually produce \$500 or more. This potentially excludes the smallest, one-person establishments. For example, in the cotton industry, with an average annual wage of \$343, many

25 In addition, they use a different source, that is, the German statistical yearbook for 1907. See Kinghorn and Nye, 'The scale of production.'. The workplace census from which we obtain our data is more detailed and has a larger coverage.

one-person establishments may not be accounted for in the census. In other industries with higher wages this is less problematic. For instance, in the foundry industry, blast furnaces, and rolling works the average annual wage was \$522, \$626, and \$571, respectively. It is unlikely that the census excluded many establishments in these industries.

The German-based distribution of employment over establishment-size classes is collected from the German workplace census of 1907. With 12 establishment-size classes, the German census provides more detail than the US data. In addition, the German census has no cut-off point and reports for each establishment-size class the number of proprietors, administrative staff members, technicians, workers, and family members employed in the establishment, and for all of these occupations the number of males and females. Given the detail provided by the German workplace census, we have adjusted the German data to fit the US definitions. Instead of all employment, we only count German labourers and family members to match US wage earners. Moreover, we leave out all one-person establishments to allow for the US cut-off point of \$500. Lastly, we aggregate both the German and US data to eight establishment-size classes, that is, 1 to 5, 6 to 20, 21 to 50, 51 to 100, 101 to 250, 251 to 500, 501 to 1,000, and 1,000+ workers. We then plot the employment distribution by establishment size and compare these between Germany and the USA.

Figure 1 shows the Kernel density plot of the employment distribution by establishment size (in log scale) for the total of industries studied in the benchmark for 1909. The graph reveals that much of the difference between the distributions

Figure 1. Kernel density plot of the employment distribution by establishment size in German and US manufacturing, 1909 (in log scale).

of Germany and the USA can be traced back to the lower establishment size classes. In line with the work of Kinghorn and Nye, we find that the employment share in relatively small establishments was larger in Germany than in the USA.²⁶ For our sample of benchmark industries the mean of the employment distribution by establishment size was 396, meaning that the average worker was employed in an establishment with about 400 wage earners. In the USA it was 749. Not surprisingly, the main difference between Germany and the USA was the former's relatively large share of employment working in establishments with fewer than 500 workers. The bulk of the US labour force was employed in establishments with more than 500 workers. Despite these differences, each country had very small as well as very large establishments, suggesting that while the shape of the distribution differs between Germany and the USA, both countries cover a comparable range of establishment size. Thus, if establishment size is a proxy for technology, then both countries had both traditional and modern elements, but in a different mix.

Breaking down manufacturing into industries, we see the same pattern, with Germany having more employment in the lower size classes (see Appendix I). There are several ways to quantify this difference between the two countries. The difference in establishment size can be described, first, by the difference in the mean of the employment distribution, that is, the size of the establishment in which the average worker is employed.²⁷ The mean, however, may fail to capture important differences in the shape of the employment distribution. For instance, while the share of employment in the tails of a normal and bimodal distribution differs substantially, the mean can still be very similar. We therefore looked at the establishment size of the first, the fifth, and the ninth deciles of the employment distribution in German and US manufacturing industries. The first and ninth deciles provide an indication of the weight in the left and right tail of the employment distribution, respectively. The fifth decile (the median) is a measure of central location, but less sensitive to outliers as compared with the mean. Table 2 reports the German/US comparative establishment size for each of these moments of the distribution.²⁸

On average, establishment size is much smaller in Germany than in the USA, particularly at the first decile. This shows that German industries employed considerably more labour in small establishments and less in large establishments. The difference is particularly large in tobacco, petroleum refining, leather, and transportation-equipment industries. In paper, chemicals, and rubber on the other hand, the difference between the two countries is relatively small. Also, in some cases the establishment size of the ninth decile in Germany is as large as, or even larger than, in the USA. This shows that although German establishments were on average smaller than in the USA, large-scale production was explored in Germany, too.

26 Kinghorn and Nye, 'The scale of production.'

27 Note that this is not the average establishment size, which is the mean of the establishment (instead of employment) distribution by establishment size.

28 Appendix I presents the full employment distribution over establishment size for all manufacturing industries in Germany and the USA that are included in the labour-productivity benchmark.

Table 2. Comparative establishment size; the mean and the first, fifth, and ninth deciles of the employment distribution by establishment size in Germany in 1909 (US = 100)

Industry	Mean	First decile	Fifth decile	Ninth decile
Manufacturing[†]	53	35	81	85
Food and kindred products	42	66	85	36
Tobacco manufactures [†]	34	72	42	16
Textile mill products	48	74	42	65
Paper and allied products	81	28	78	84
Chemical and allied products	79	72	74	110
Petroleum and coal products	28	196	36	12
Rubber products	102	78	83	100
Leather and leather products	102	30	41	273
Stone, clay, and glass products	78	38	84	48
Primary metal products	53	40	44	76
Transportation equipment	74	38	36	95
Spearman's rank correlation with the labour-productivity gap (Table 1)	0.19	0.20	-0.07	0.36

[†] Total manufacturing is a weighted average of the underlying manufacturing industries. *Sources:* see text.

Are these differences between Germany and the USA in establishment size related to our new comparative labour-productivity levels presented in the previous section? No, the ranking of comparative labour productivity reported in Table 1 looks very different from the ranking of comparative establishment size listed in Table 2. The Spearman's rank correlation between comparative establishment size and comparative labour productivity is very weak, irrespective of the measure of establishment size used in the correlation. This means that it is premature to conclude – as suggested in the previous section – that the strong comparative labour-productivity performance in several German industries resulted from a large scale of production relative to other German industries. This does not imply, however, that establishment size was unimportant for labour productivity. Rather, the correlations in the bottom row of Table 2 show that establishment size was not the only determinant of the labour-productivity gap between Germany and the USA. Other factors were important, too, and the effect of establishment size needs to be isolated from alternative determinants of labour productivity.

ESTABLISHMENT SIZE AND LABOUR PRODUCTIVITY

We can use the data presented in the previous two sections to regress establishment size on labour productivity in an attempt to exclude the effect of other factors. Figure 2 presents the least-squares estimate of the relation between the mean establishment size of the employment distribution and labour

Figure 2. Partial residual plot of labour productivity against the mean of the employment distribution by establishment size; German and US manufacturing industries in 1909.

productivity, controlling for other determinants of labour productivity.²⁹ The graph includes 22 observations, namely the 11 industries included in the benchmark for both Germany and the USA.³⁰ There is a clear positive relation with a correlation coefficient of 0.84, suggesting that establishment size indeed mattered for labour productivity.

While the regression line slopes upward, the coefficient on the slope is not significantly different from zero. With the limited number of observations at our disposal, the coefficients are imprecisely estimated. We overcome this problem by pursuing a novel empirical strategy. In a first step we analyse the relation between establishment size and labour productivity by exploring the variation across US states, instead of the country-level data presented in Tables 1 and 2. This yields for each manufacturing industry a theoretical maximum number of observations equal to the number of US states in 1909, that is, 46. In practice the number is lower because manufacturing activities were regionally concentrated. We therefore end up with a total of 198 state-industry combinations for the sample of 11 manufacturing industries included in the benchmark. This is more than sufficient for an accurate estimation. The analysis based on the US

29 We estimate $y_{ij} = X_{ij}\beta + \alpha_i + \gamma_j + u_{ij}$ with y_{ij} the level of labour productivity in industry i in country j , X_{ij} a 1×3 regressor matrix that in addition to the intercept and mean establishment size also contains a control for capital intensity (proxied by horsepower intensity), α_i the unobserved individual effect of industry i , γ_j the unobserved individual effect of country j , and an error term u_{ij} . The horsepower data are taken from the German workplace census of 1907 and the US census of manufactures of 1909. These are the same sources that provide the data on the distribution of employment over establishment size.

30 Labour productivity is expressed in 1909 US dollars. German output values are converted to US dollars using the PPPs reported in Table 1.

state data is also more reliable because we can add more controls than is possible with the country-level data.³¹ We estimate the following equation:

$$y_{ij} = X_{ij}\beta + \alpha_i + \gamma_j + u_{ij}, \quad (1)$$

with y_{ij} the level of labour productivity in industry i in US state j , X_{ij} a 1×4 regressor matrix that in addition to the intercept and a measure of establishment size also includes controls for labour quality and capital intensity, α_i the unobserved individual effect of industry i and γ_j the unobserved individual effect of state j and an error term u_{ij} . With respect to the explanatory variable of interest, that is, establishment size, there are several measures that we can use. As previously noted, the size of the establishment in which the average worker is employed (the mean of the employment distribution by establishment size) does not efficiently capture the weight in the tails of the distribution. Therefore, we divide the employment distribution into deciles and sequentially estimate the model using, in succession, the establishment size at the first until the ninth decile as our measure of establishment size. This way we explore the shape of the full employment distribution and see which areas under the distribution are important for aggregate labour productivity levels.

In a second step we use the relation between labour productivity and establishment size, which we estimated on the basis of US state data, to correct the German/US labour-productivity gap for differences in establishment size. This makes sense only when our estimates based on US state data capture the correlation between labour productivity and establishment size independent of the country-specific circumstances in which industries operate. We do so by controlling in our analysis for differences in factor costs (using horsepower intensity data), differences in labour quality (using wage rates as a crude proxy), and differences in institutional setting (using fixed effects to capture all unobserved heterogeneity). Unfortunately, our fixed effects approach may not suffice to truly eliminate the effect of institutions from our estimates; this is because the variation in institutional setting across US states is limited by the fact that they operated under the same US constitution. Thus, the institutional variation for which we control is not as substantial as between Germany and the USA. This may have implications for the validity of our analysis, and we return to this problem in the next section, particularly in relation to antitrust regulations.

An advantage of the US state data is the considerable variation in the employment distribution by establishment size. More to the point, in all manufacturing industries the German employment distribution falls within the range of distributions covered by US states, suggesting that the estimated coefficients are applicable to Germany, too. Take for instance the tobacco industry, for which Figure 3 presents the employment distribution by establishment size. The thick black

31 The constraint is posed by the German data, which do not provide information on wages and salaries, rendering it impossible to control for differences in labour quality.

Figure 3. Kernel density plots of the employment distribution by establishment size in German and US tobacco, 1909.

line represents Germany, the dotted black line is the USA, and the thin light grey lines are US states that are involved in the manufacturing of tobacco. The US states cover a broad range of different distributions with some having mainly small establishments, others with predominantly large establishments and several including both small and large establishments. Moreover, the employment distribution of, for instance, Tennessee (marked black line) resembles that of Germany quite closely.

Table 3 reports the results of the regression analysis. The estimates have important implications for the notion that a large tail of small workshops suppresses average labour-productivity levels in industries. Variation in the size of establishments at the first until third decile does not correlate with variation in labour productivity. The size of establishments does not impact on aggregate labour productivity until at least 40 per cent of the labour force is taken into account. Figure 4 shows the *P*-value for the coefficient on establishment size at different deciles of the employment distribution as well as the average establishment size of those deciles for the 198 US state-industry observations included in the analysis. From the fourth decile onwards the correlation between establishment size and labour productivity is statistically significant. The average establishment size at the fourth decile is 361, that is, a type of establishment very different from the small workshops that Hannah identified as a potential determinant of aggregate labour

Table 3. OLS regression results

	<i>Dependent variable:</i>								
	Gross output (\$1,000) per employee in 1909								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
First decile	0.070 (0.096)								
Second decile		0.090 (0.095)							
Third decile			0.116 (0.093)						
Fourth decile				0.231** (0.093)					
Fifth decile (median)					0.226*** (0.082)				
Sixth decile						0.187** (0.084)			
Seventh decile							0.204** (0.082)		
Eighth decile								0.198** (0.091)	
Ninth decile									0.206** (0.096)
Horse power intensity (HP per worker)	0.063*** (0.025)	0.066*** (0.024)	0.063*** (0.024)	0.071*** (0.024)	0.072*** (0.024)	0.070*** (0.024)	0.065*** (0.024)	0.064*** (0.024)	0.064*** (0.024)
Wages per worker (thousands of \$ per worker)	4.491*** (1.336)	4.539*** (1.337)	4.584*** (1.335)	4.687*** (1.313)	4.725*** (1.306)	4.680*** (1.320)	4.731*** (1.314)	4.699*** (1.321)	4.659*** (1.312)
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	198	198	198	198	198	198	198	198	198
R^2	0.810	0.811	0.811	0.817	0.819	0.816	0.817	0.815	0.815
Adj. R^2	0.739	0.739	0.740	0.748	0.751	0.746	0.748	0.746	0.746

Notes: Standard errors are given in parentheses with stars indicating * $P < 0.1$, ** $P < 0.05$, *** $P < 0.01$.

Figure 4. Average US establishment size and *P*-values for the coefficient on establishment size at different deciles of the employment distribution (1909).

productivity levels.³² The latter finding, that the smallest establishments do not seem to have influenced aggregate labour productivity, suggests that the German/US labour-productivity gap was not primarily driven by a large tail of workshops with fewer than 10 workers in Germany. More important seems to have been the allocation of the bulk of employment in the mid-ranges of establishment size, rather than in the absolute tails of the distribution.

Using the coefficient on establishment size obtained on the basis of the analysis on US states, we can calculate the increase in German labour-productivity levels resulting from a change in the size of establishments from German to US levels. This can be done successively for the size of establishments at each decile of the employment distribution that were significant in our regression analysis. Table 4 presents the results of this counterfactual exercise. The first column reports the original benchmark estimate of German/US comparative labour productivity, the second column the establishment-size-adjusted levels, and the final column the resulting decrease of the original labour-productivity gap. It is clear that on the aggregate level Germany could gain from increasing the scale of production. Our estimates suggest that about a quarter of the labour-productivity gap can be accounted for by differences in establishment size.³³

³² Hannah, 'Logistics'.

³³ The differences in establishment size are based on the distribution of wage earners over establishment size. As discussed above, we have adjusted the German data to fit the US definitions. The adjustment included cutting off all one-person establishments in Germany and leaving out salaried personnel. To see how sensitive our analysis is for these modifications, we calculated the establishment-size differences between Germany and the USA using for the former the distribution of total employment over establishment size. This changes the labour-productivity gains achievable in Germany by increasing establishment size to US levels very little. Instead of reducing the labour-productivity gap by 26 per cent, the gap reduces by 24 per cent.

Table 4. German/US comparative labour productivity in manufacturing in 1909; original and establishment-size adjusted estimates

Adjustment made for differences in establishment size at the	Original (US = 100)	Size adjusted (US = 100)	Decrease labour productivity gap (%)
Fourth decile	61	71	26
Fifth decile (median)	61	71	26
Sixth decile	61	72	27
Seventh decile	61	73	29
Eighth decile	61	70	23
Ninth decile	61	70	23
Average of above	61	71	26

Sources: see text.

LABOUR PRODUCTIVITY IN SMALL ESTABLISHMENTS

While the larger part of the labour-productivity gap remains unaccounted for, meaning that other factors were equally or perhaps even more important, the potential gains for Germany that could be realised through increasing the scale of production were considerable. In contrast to what Hannah suggests, it was not the bulk of small workshops that held back Germany's overall labour-productivity performance.³⁴ The allocation of employment in the mid-ranges of establishment size seems more important. How can we explain this relatively minor effect of small establishments in German industry on relative aggregate productivity levels? We can observe a purely statistical effect. Although the number of small establishments is high in comparison with the USA, the employment weight of these firms in the calculation of average output per worker for each industry is quite low. Something similar was observed in a German/British productivity comparison for 1935/36, where the different cut-off points (the British census excluded firms employing less than 11 persons, the German excluded less than five) resulted in an possible overstatement of British labour productivity for total manufacturing vis-à-vis Germany of not more than two percentage points.³⁵

It matters very little whether labour productivity in small workshops was relatively low or not; the small share of the labour force employed in these establishments lacked the weight to impact aggregate performance levels. Therefore, Hannah's suggestion that the tail of small workshops determined Germany's overall low productivity seems to lead nowhere.³⁶ Of course, he may still have been right to point out that small establishments were less productive than larger ones. The evidence presented here does not support a final conclusion regarding this issue. Neither does the existing literature. In fact, based on the literature one can argue

³⁴ Hannah, 'Logistics'.

³⁵ Fremdling et al., 'British and German manufacturing', p. 372.

³⁶ Hannah, 'Logistics'.

either way, that is, that labour productivity in small establishments was relatively low or that it was not.

Labour productivity in small workshops must have been low if we accept the idea that modern technology of the Second Industrial Revolution was capital intensive and optimally explored only with large production units. Constraints to the adoption of the new technologies will then result in a relatively large tail of small establishments. Particularly important in this respect are labour-market differences between Germany and the USA at the start of the twentieth century. The much lower levels of real wages in Germany may have led to lower levels of capital replacement than in the USA.³⁷ Hoffmann's capital-stock estimates for Germany are perhaps problematic, but we know that German horsepower intensities in manufacturing before WWI were less than half of the US level.³⁸ This suggests a comparatively slow adjustment of the capital stock, arguably leading to a high number of establishments retaining traditional production techniques that can be efficiently operated with small-scale production. Note that such a development path can be a rational adaption to the country-specific conditions in which establishments operate, rather than a reflection of low technological standards or low economic efficiency.³⁹

On the other hand, it could also be argued that in the institutional setting of Germany small-scale production did not convey a labour-productivity disadvantage *per se*. For instance, Gary Herrigel stressed the decentralised industrial order of small and medium sized firms in many parts of Germany (in particular textile, machine, fine-mechanical, and optical-equipment producers) consisting of subcontracting networks of small firms.⁴⁰ These firms shared information about markets, technologies, and skills, set quality standards, and were characterised by high quality specialty production and flexible production systems. Firms within such systems were different from the large-scale industries and were less capital intensive but did not necessarily specialise in low value added manufacturing as it was based on skills and customised production.

In addition, in Germany cartels may have reduced transaction costs, encouraging outsourcing of production activities and, in theory at least, decreasing the size of establishments at no loss of productive efficiency.⁴¹ The effect of cartels on labour productivity is equivocal, however, as they can also reduce competitive pressure, leaving inefficiencies in the production process unpunished. Moreover, cartels typically involved larger establishments, and it is therefore unlikely that these affected levels of labour productivity in small workshops.

This leaves the possibility that cartels mattered for efficiency levels in bigger factories that employed the bulk of the labour force and for which we find a significant correlation with labour productivity in the US state data. We think it unlikely, though, as in practice the statistical evidence on the relation between

37 Williamson, 'The evolution'; Broadberry and Burhop, 'Real wages'.

38 Hoffmann, *Das Wachstum*; Broadberry, *The productivity race*.

39 Salter, *Productivity*, pp. 41 and 73.

40 Herrigel, *Industrial constructions*.

41 Kinghorn and Nye, 'The scale of production'; Hannah, 'The American miracle'; Cheffins, 'Mergers'.

German cartels and labour productivity is ambiguous. While Kinghorn argues that German coal and iron and steel cartels around the turn of the century did not lead to true monopoly power, Burhop and Lübbers find that in the case of German coal-mining corporations productivity was not significantly affected by cartel membership.⁴² We cannot control for cartel membership in our analysis with US state data, because antitrust regulations did not allow the formation of cartels in the USA, but lacking evidence of a positive labour-productivity effect of cartels in Germany we do not see reason to question the validity of our analysis.

CONCLUSION

In this paper we explore the notion that at the start of the twentieth century German/US comparative manufacturing labour productivity was partly determined by the mix of old and new production technologies within industries. New technology of the Second Industrial Revolution typically involved mass production techniques with high fixed costs but low variable costs; the high minimum efficient scale of this modern technology implies that it could only be operated cost efficiently in large establishments. It follows that in a comparison between two countries, the country with the larger weight in the right tail of the employment distribution by establishment size makes more extensive use of modern technology. Given the low variable costs of the new technology, realised through economies of scale, the country with the smallest weight in the left tail enjoys a labour-productivity advantage. In line with this idea, Hannah suggests that it may have been the larger number of small workshops in German manufacturing that drove its overall low productivity level.⁴³

We tested this hypothesis in four steps. We first presented a new benchmark of German/US manufacturing labour productivity for 1909 to accurately measure the labour-productivity gap. The benchmark shows that German manufacturing performed at 61 per cent of the US level, but with a wide range of comparative performance in underlying industries. In a second step we compared the employment distribution by establishment size between both countries and concluded that in Germany the left tail was heavier than in the USA and vice versa for the right tail. Then, using US state data for 1909, we presented evidence that establishment size was indeed positively correlated with labour productivity. The coefficients of these estimates suggest that the labour productivity increase in German manufacturing associated with a rise in establishment size to US levels would reduce the original labour-productivity gap by about 25 per cent. The downward pressure on German labour productivity did not, however, come from establishments in the very left tail; even if workshops of fewer than 10 employees were considerably less productive than their larger counterparts, which is not at all certain, they lacked the necessary weight to influence aggregate performance levels.

42 Kinghorn, 'Kartell or cartel?'; Burhop and Lübbers, 'Cartels'.

43 Hannah, 'Logistics'.

REFERENCES

- Allen, R. C. (1979) International competition in iron and steel, 1850–1913. *Journal of Economic History*, 39, 911–37.
- Braun, H. J. (1990) *The German Economy in the Twentieth Century: The German Reich and the Federal Republic* (London: Routledge).
- Broadberry, S. N. (1994) Technological leadership and productivity leadership in manufacturing since the industrial revolution: implications for the convergence debate. *Economic Journal*, 104, 291–302.
- Broadberry, S. N. (1997) *The Productivity Race: British Manufacturing in International Perspective, 1850–1990* (Cambridge: Cambridge University Press).
- Broadberry, S. N., and Burhop, C. (2007) Comparative productivity in British and German manufacturing before World War II: reconciling direct benchmark estimates and time series projections. *Journal of Economic History*, 67, 315–349.
- Broadberry, S. N., and Burhop, C. (2008) Resolving the Anglo-German industrial productivity puzzle, 1895–1935: a response to Professor Ritschl. *Journal of Economic History*, 68, 930–934.
- Broadberry, S. N., and Burhop, C. (2010) Real wages and labor productivity in Britain and Germany, 1871–1938: a unified approach to the international comparison of living standards. *Journal of Economic History*, 70, 400–27.
- Broadberry, S. N., and Fremdling, R. (1990) Comparative productivity in British and German industry 1907–37. *Oxford Bulletin of Economics and Statistics*, 52, 403–421.
- Broadberry, S. N., and Irwin, D. (2006) Labor productivity in the United States and the United Kingdom during the nineteenth century. *Explorations in Economic History*, 43, 257–79.
- Burhop, C. (2008) The level of labour productivity in German mining, crafts, and industry in 1913: evidence from output data. *European Review of Economic History*, 12, 201–19.
- Burhop, C., and Lübbers, L. (2009) Cartels, managerial incentives, and productive efficiency in German coal mining, 1881–1913. *Journal of Economic History*, 69, 500–527.
- Chandler, A. (1990) *Scale and Scope: The Dynamics of Industrial Capitalism* (Harvard: Belknap Press of Harvard University Press).
- Cheffins, B. R. (2003) Mergers and corporate ownership structure: the United States and Germany at the turn of the twentieth century. *American Journal of Comparative Law*, 51, 473–503.
- David, P. (1975) *Technical Choice, Innovation and Economic Growth. Essays on American and British Experience in the Nineteenth Century* (Cambridge: Cambridge University Press).
- Field, A. J. (1985) On the unimportance of machinery. *Explorations in Economic History*, 22, 378–401.
- Fremdling, R., de Jong, H. J., and Timmer, M. P. (2007) British and German manufacturing productivity compared: A new benchmark for 1935/36 based on double deflated value added. *Journal of Economic History*, 67, 350–78.
- Gerschenkron, A. (1962) *Economic Backwardness in Historical Perspective: A Book of Essays* (Cambridge: Cambridge University Press).
- Habakkuk, H. J. (1962) *American and British Technology in the Nineteenth Century. The Search for Labour-Saving Inventions* (Cambridge: Cambridge University Press).
- Hannah, L. (1995) The American miracle, 1875–1950, and after: a view in the European mirror. *Business and Economic History*, 24, 197–220.
- Hannah, L. (2008) Logistics, market size, and giant plants in the early twentieth century: a global view. *Journal of Economic History*, 68, 46–78.
- Herrigel, G. (1996) *Industrial Constructions: The Sources of German Industrial Power* (Cambridge: Cambridge University Press).
- Hoffmann, W. G. (1965) *Das Wachstum der Deutschen Wirtschaft seit der Mitte des 19. Jahrhunderts* (Berlin: Berlin-Verlag) [The growth of the German economy since the mid-nineteenth century].
- Kinghorn, J. (1996) Kartell or cartel? Evidence from turn of the century German coal, iron and steel industries. *Journal of Economic History*, 56, 491–92.
- Kinghorn, J., and Nye, J. (1996) The scale of production in western economic development: a comparison of official industry statistics in the United States, Britain, France, and Germany, 1905–1913. *Journal of Economic History*, 56, 90–112.
- Landes, D. S. (1969) *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present* (Cambridge: Cambridge University Press).

- Melitz, M. (2003) The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, 71, 1695–1725.
- Ritschl, A. (2008) The Anglo-German industrial productivity puzzle, 1895–1935: a restatement and a possible resolution. *Journal of Economic History*, 68, 535–65.
- Rostas, L. (1943) Industrial production, productivity and distribution in Britain, Germany and the United States. *Economic Journal*, 53, 39–54.
- Salter, W. (1966) *Productivity and Technical Change* (Cambridge: Cambridge University Press).
- Svnnilsson, I. (1954) *Growth and Stagnation in the European Economy* (Geneva: United Nations).
- Temin, P. (1971) Labour scarcity in America. *Journal of Interdisciplinary History*, 1, 251–64.
- Veenstra, J. (2014) Missed opportunities? Germany and the transatlantic labor-productivity gap, 1900–1940. PhD thesis, University of Groningen.
- Veenstra, J. (2015) Output growth in German manufacturing, 1907–1936. A reinterpretation of time-series evidence. *Explorations in Economic History*, 57, 38–49.
- Williamson, J. G. (1995) The evolution of global labor markets since 1830: background evidence and hypotheses. *Explorations in Economic History*, 32, 141–96.

PRIMARY SOURCES

- Gewerbliche Betriebsstatistik [Business statistics]. In: *Berufs- und Betriebszählung vom 12. Juni 1907* [Occupational and workplace census of the German Empire of 12 June 1907] (1907), (Berlin).
- Statistisches Jahrbuch für das deutsche Reich* [Statistical yearbook of the German Empire] (1907–1912), (Berlin).
- Ergänzungsheft zu die Ergebnisse der deutschen Produktionserhebungen [Special edition to the reports of the German production surveys]. In: *Vierteljahrshefte zur Statistik des deutschen Reichs* [Quarterly statistics of the German empire], *Ergänzungsheft 3* (1913), (Berlin).
- Ergebnisse der deutschen Produktionserhebungen [Reports of the German production surveys]. In: *Vierteljahrshefte zur Statistik des deutschen Reichs* [Quarterly statistics of the German empire], *Ergänzungsheft 2* (1913), (Berlin).
- Industrielle Produktionsstatistik. Sammlung produktionsstatistischer Nachkriegszahlen bis zum Jahre 1926 mit Ergänzungen bis zum Jahre 1927 [Industrial production statistics. Collected production statistics from the postwar era to 1926 with additions until 1927]. In: *Sonderhefte zu Wirtschaft und Statistik* [Special edition to Economy and Statistics] (1928), 4 (Berlin).
- Industrielle Produktionsstatistik. Sammlung produktionsstatistischer Nachkriegszahlen bis zum Jahre 1928 [Industrial production statistics. Collected production statistics from the postwar era to 1928]. In: *Sonderhefte zu Wirtschaft und Statistik* [Special edition to Economy and Statistics], issue 6 (1929), (Berlin).
- Industrielle Produktionsstatistik. Sammlung von Ergebnissen der Produktions- und Vorratsstatistik bis Mitte 1934 [Industrial production statistics. Collected reports on production and inventory statistics until the middle of 1934]. In: *Sonderhefte zu Wirtschaft und Statistik* [Special edition to Economy and Statistics], issue 13 (1934), (Berlin).
- United States Department of Commerce: Bureau of the Census (1913) *Thirteenth Census of the United States Taken in the Year 1910* (Washington D.C.).
- Ausschuss zur Untersuchung der Erzeugungs- und Absatzbedingungen der deutschen Wirtschaft [Commission for the study of production and market conditions in the German economy] (1933) Die deutsche Zellstoff-, Holzschliff-, Papier- und Pappenindustries [The German pulp and paper industries]. In: *Verhandlungen und Berichte des Unterausschusses für allgemeine Wirtschaftsstruktur* [Reports of the sub-commission for the general economic structure], (Berlin).
- Ausschuss zur Untersuchung der Erzeugungs- und Absatzbedingungen der deutschen Wirtschaft [Commission for the study of production and market conditions in the German economy] (1931) Die deutsche Glasindustrie [The German glass industry]. In: *Verhandlungen und Berichte des Unterausschusses für allgemeine Wirtschaftsstruktur* [Reports of the sub-commission for the general economic structure], (Berlin).

APPENDIX I

The employment distribution by establishment size in manufacturing industries

Sources: See text.

APPENDIX II

Robustness of the PPPs

The PPPs used to convert German gold marks into US dollars rely on the German/US price ratio of products. If the total production value and the total production quantity of a particular product are available in the historical sources, we can calculate a unit value for that product. Products for which we have unit values in both Germany and the USA can then be compared, leading to a unit value ratio that expresses the relative price level for that product. We then calculate a weighted average over all unit value ratios belonging to the same Standard Industrial Classification (SIC) 2-digit industry, sequentially using the product output shares of the two countries and then taking the Fisher index thereof.

Table A1. Output coverage and number of unit value ratios

Industry	Share in compared output value		Number of unit value ratios
	Germany	USA	
Manufacturing	61	50	74
Food and kindred products	4	8	6
Tobacco manufactures	...	...	
Textile mill products	58	30	11
Paper and allied products	100	60	3
Chemical and allied products	143	38	15
Petroleum and coal products	86	86	8
Rubber products	64	98	1
Leather and leather products	79	120	5
Stone, clay, and glass products	43	42	2
Primary metal products	74	6	18
Transportation equipment	68	57	5

Sources: See text.

Note that in two cases the unit value ratios cover more than the output included in the labour-productivity comparison. The primary sources sometimes classify products ‘wrongly’, that is, different from the SIC. Although in such cases the unit value ratios of these products are reclassified here in the ‘correct’ industry group, their output usually cannot be included in the labour-productivity comparison. For instance, the historical sources classify the product ‘leather gloves’ in the apparel industry, whereas the SIC assigns it to leather production. This means that we include the unit value ratio of ‘leather gloves’ in the PPP for the leather industry. Unfortunately, the primary sources do not report the labour input involved in the production of ‘leather gloves’, and therefore we cannot include this product in the calculation of labour-productivity levels. So the information is used only to improve the quality of the PPP for the leather industry and not for comparing levels of output and employment.