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Source: *The Journal of Economic History*, Vol. 53, No. 4, (Dec., 1993), pp. 772-795
Published by: Cambridge University Press on behalf of the Economic History Association
Stable URL: http://www.jstor.org/stable/2122639
Accessed: 07/08/2008 11:04

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Manufacturing and the Convergence Hypothesis: What the Long-Run Data Show

STEPHEN N. BROADBERRY

The commonly accepted chronology for comparative productivity levels, based on GDP data, does not apply to the manufacturing sector, which shows evidence of a much greater degree of stationarity of comparative labor productivity performance among the major industrialized countries of Britain, Germany, and the United States. These results for manufacturing suggest that convergence of GDP per worker must have occurred through trends in other sectors and through compositional effects of structural change. The persistent, large labor productivity gap between the United States and Europe cannot be explained simply by differences in capital per worker, but is related to technological choice.

This article presents estimates of relative levels of labor productivity in manufacturing since 1870 for three of the major manufacturing economies. Comparative labor productivity trends in manufacturing for Britain, the United States, and Germany are very different from the trends in comparative GDP per employee that inform most accounts of long-run productivity performance.[1] First, the whole-economy evidence suggests that the United States overtook Britain as the labor productivity leader in the early 1890s and then forged substantially ahead to 1950, with Britain pulling close to American levels by the late 1980s. However, the evidence from manufacturing suggests that U.S. labor productivity levels were already about twice the British level in 1870, and that U.S. superiority was still close to this two-to-one level in the late 1980s despite substantial swings in productivity in the intervening years, particularly across the two world wars. Second, the whole-economy evidence suggests that German labor productivity levels were substantially below the British level in 1870 and caught up only by the 1970s. However, the evidence from manufacturing suggests that German labor productivity levels were already close to British levels in the late nineteenth century. Germany pulled substantially ahead after

The Journal of Economic History, Vol. 53, No. 4 (Dec. 1993). © The Economic History Association. All rights reserved. ISSN 0022-0507.

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I am particularly grateful to Bart van Ark for data and comments throughout this research project. I have also received helpful comments from Nick Crafts, Angus Maddison, Mary O'Mahony, Dirk Pilat, and seminar participants at the European Historical Economics Conference in Copenhagen, the University of Wales, and the Ifo Institute in Munich. I am responsible for any remaining errors.

[1] Maddison, *Phases* and *Dynamic Forces*; Feinstein, "Economic Growth"; and Baumol, "Productivity Growth."

World War II, particularly during the 1970s, though the gap narrowed substantially during the 1980s.

Although these trends are consistent with a form of catching-up—since a period when one country widens its labor productivity lead is followed by a period when the gap narrows—they do not suggest that the three countries should be seen as converging on the same level of labor productivity.[2] Thus, rather than suggesting global convergence, they are consistent with a process of local convergence between Britain and Germany but a persistent large gap between both European economies and that of the United States.[3]

I will first set out the details of the calculations—which involve matching time series data on labor productivity growth with benchmark estimates of comparative labor productivity levels—and then consider the implications of the manufacturing results for the whole-economy estimates of Angus Maddison.[4] The results suggest that the broad trends of the two series are reconcilable. I then consider the implications for the convergence hypothesis before looking at the role of capital, providing estimates of total factor productivity to complement the figures on labor productivity. The final section examines the implications of technological choice for productivity estimates by manufacturing branch.

LABOR PRODUCTIVITY IN MANUFACTURING

Time series on labor productivity in manufacturing can be obtained from 1870 on for the countries considered in this article. These time series can then be linked to benchmark estimates of comparative labor productivity levels, to provide a reconciliation of evidence on levels and rates of growth of labor productivity.

The extrapolation of benchmark comparisons to other years on the basis of time series does not necessarily yield identical results compared with actual benchmark year comparisons, because of traditional index number problems.[5] The existence of a number of benchmark comparisons between Britain and the United States and between Britain and Germany thus provides a useful check on the extrapolations. As prewar benchmark estimates exist only for manufacturing and not for the rest of the economy, this consistency check between time series and cross-sectional evidence is not possible for Maddison's extrapolations based on GDP per worker, which form the basis of the standard literature on long-run productivity performance.[6]

[2] Abramovitz, "Catching Up"; and Baumol, "Productivity Growth."
[3] Durlauf and Johnson, "Local versus Global Convergence."
[4] Maddison, *Dynamic Forces*.
[5] Krijnse Locker and Faerber, "Space and Time Comparisons"; and Szilagyi, "Procedures for Updating."
[6] Maddison, *Phases* and *Dynamic Forces*.

TABLE 1
MANUFACTURING OUTPUT PER PERSON EMPLOYED (U.K. = 100)

Year	U.S./U.K.	Germany/U.K.
1869	203.8	—
1875	—	100.0
1879	187.8	—
1882	—	83.6
1885	—	94.5
1889	195.4	94.7
1899	194.8	99.0
1907	192.0 (201.9)	106.4
1913	212.9	119.0
1920	222.8	—
1925	234.2	95.2
1929	249.9	104.7
1935	207.8	102.0 (102.0)
1937	208.3 (208.3)	99.9
1950	262.6 (273.4)	96.0 (99.5)
1958	250.0	111.1
1968	242.6 (272.7)	120.0 (130.4)
1975	207.5 (224.7)	132.9
1977	229.6 (251.0)	148.6
1980	192.8	140.2
1984	183.3	122.7
1987	188.8 (186.6)	107.8 (112.7)
1989	177.0	105.1

Notes: 1937 is the benchmark year from which the U.S./U.K. time series are extrapolated, 1935 for the Germany/U.K. time series. The figures in parentheses are actual benchmark comparisons. In some cases the comparisons are based on production census data for slightly different years (for instance, 1967 for Germany and the United States compared with 1968 for the United Kingdom), and an adjustment has been made to bring the comparison onto a single-year basis.
Sources: The benchmark comparisons for U.S./U.K. figures are derived as follows: 1907, Broadberry, "Comparative Productivity"; 1937, Rostas, *Comparative Productivity*; 1950, Paige and Bombach, *A Comparison*; 1968, Smith, Hitchens, and Davies, *International Industrial Productivity*; 1975, van Ark, "Comparative Levels of Manufacturing"; 1977, Smith, "Changes in Comparative"; 1987, van Ark, "Comparative Productivity in British." The benchmark comparisons for Germany/U.K. figures are derived as follows: 1935, Broadberry and Fremdling, "Comparative Productivity"; 1950, census data converted at "proxy" purchasing power parity for manufactured products from Gilbert and Kravis, *An International Comparison*; 1968, Smith, Hitchens, and Davies, *International Industrial Productivity*; 1987, O'Mahony, "Productivity Levels." Time series of output and employment are from Appendix Table 1.

Benchmark Estimates

The time series extrapolations shown in Table 1 are based on benchmark comparisons for the 1930s (other available benchmark estimates are reported in parentheses). All comparisons are made on a bilateral basis with the United Kingdom. Pre-1945 estimates are based on a direct comparison of physical output per worker, following the methodology of Laszlo Rostas.[7] Post-1945 estimates are based on comparisons of prices for individual products, following the methodol-

[7] Rostas, *Comparative Productivity*.

ogy set out by Deborah Paige and Gottfried Bombach.[8] The average price ratio is used to convert the output value in different countries into a common currency. In general the price ratios are unit value ratios (UVRs), obtained from the production censuses in each country as the quotient of the ex-factory sales value and the corresponding quantities.[9] However, for the Germany/U.K. 1950 comparison, the price ratios are proxy PPPs (purchasing power parities) for expenditure on manufactures, from Milton Gilbert and Irving Kravis.[10]

Time Series

The benchmark estimates leave too many gaps to analyze long-term comparative productivity performance in detail. Other authors have provided long time series of per capita income and labor productivity for the whole economy by linking national time series of GDP and population or labor input to benchmark estimates for a particular year.[11] In a similar way this study combines the benchmark results with time series on output and employment in manufacturing for the years for which there are no benchmark estimates. In Table 1 the starting point for the extrapolations is the mid-1930s, or roughly halfway through the sample period. This is preferable to using very recent benchmarks, which would require extrapolations of more than 100 years to obtain estimates for the 1870s.

It is useful to compare the extrapolations from the mid-1930s benchmarks with the other direct benchmark comparisons reported in parentheses. The results are in general reassuringly close. The time series are presented in detail in Appendix Table 1, but it will be useful to point out here some of the general principles followed. First, it was important to ensure that the series be collected on the same basis for different countries. For the post-1950 period the time series generally refer to production census information on net output and employment, with net output deflated by a postwar price index for manufactures. However, for the prewar period, given the general unavailability of reliable time series on real net output, industrial production indices were used. For all three countries those indices were based on gross output indicators for individual industries, weighted by net output or employment shares.[12] These series have the added advantage of being consistent with the prewar benchmark comparisons, which are also based on gross output.

Second, time series of productivity can be strongly affected by using different sources for output and employment—yet another reason to use

[8] Paige and Bombach, *A Comparison of National Output*.

[9] See Maddison and van Ark, "Comparisons of Real Output," for a discussion of the methodology.

[10] Gilbert and Kravis, *An International Comparison*.

[11] Maddison, *Phases* and *Dynamic Forces*.

[12] Fabricant, *The Output of Manufacturing*; and Carter, Reddaway, and Stone, *The Measurement of Production*.

production census data. Third, in some cases time series for "industry" need to be purged of mining, public utilities, and construction. For Germany, the prewar output and employment series had to be recalculated for manufacturing only.

Long-Term Trends

The first conclusion to draw from Table 1 is that there has been a substantial U.S. lead in manufacturing labor productivity going right back to 1869. Indeed, it seems likely that the United States had a two-to-one productivity advantage even in the mid-nineteenth century.[13] The estimates in Table 1 suggest a widening of the U.S./Britain gap across World War I, followed by a narrowing during the Depression of the 1930s, which hit the United States more severely than Britain. A further widening of the gap occurred across World War II, followed by a narrowing through to the 1980s. This time series evidence suggests that the U.S./U.K. labor productivity gap in 1987 was roughly equal to the gap in 1879, nearly 110 years earlier.

The second conclusion apparent from Table 1 is that labor productivity in Germany was close to British levels from the 1870s to 1890s and that although Germany pulled ahead somewhat by 1913, World War I provided a setback; between the wars labor productivity in Germany remained close to the British level. Between World War II and 1980, rapid labor productivity growth propelled Germany into a lead over Britain of nearly 50 percentage points; but the 1980s saw a dramatic reversal, with a German lead of under 10 percentage points by the late 1980s.

These results suggest a long-run stationarity of comparative labor productivity levels in manufacturing over a period of about 120 years. This is in marked contrast to the findings of convergence among the major industrialized countries based on data on GDP per worker. Thus it will be necessary to consider the issue of the reconciliation of the results for manufacturing and those for the whole economy in the next section.

First, however, note that these results are unlikely to be substantially altered by using hours worked rather than number of employees as the labor input. This article concentrates on output per worker because there is little firm historical information on hours worked. However, from what is known about working hours in history, it seems reasonable to conclude that hours have moved in similar ways in Britain, the United States, and Germany since the 1870s. Maddison provides figures for the whole economy, but for the pre-1950 period little is known about hours outside manufacturing, so they can be regarded as representative of the

[13] Broadberry, "Comparative Productivity"; and James and Skinner, "The Resolution," p. 527.

TABLE 2
GDP PER PERSON EMPLOYED (U.K. = 100)

	Paasch-type PPPs		Fisher-type PPPs	
Year	U.S./U.K.	Germany/U.K.	U.S./U.K.	Germany/U.K.
1870	95.1	47.8	105.9	48.8
1890	98.1	52.3	109.2	53.4
1913	127.9	62.9	142.4	64.1
1929	154.0	63.1	171.4	64.4
1938	143.0	73.4	159.3	74.9
1950	167.4	62.1	186.4	63.3
1960	167.5	88.4	186.5	90.2
1973	151.6	102.6	168.8	104.7
1987	128.9	103.5	143.5	105.6

Note: In addition to the results using Maddison's Paasche-type PPPs of national currencies to U.S. dollars, results using Fisher-type PPPs are presented for comparability with Table 1.
Source: 1985 GDP at national currencies and the indices of GDP and employment are derived from Maddison, *Dynamic Forces*.

manufacturing sector.[14] However, for the post-1950 period, it is possible to obtain more detailed estimates for manufacturing alone. Bart van Ark's estimates suggest that by 1987 differences in hours of work would lower the U.S./U.K. productivity ratio by about 8 percent and raise the Germany/U.K. ratio by a similar amount.[15] Clearly these adjustments are not trivial, but neither do they substantially change the overall picture of the productivity rankings among the three economies.

RECONCILING PRODUCTIVITY ESTIMATES FOR MANUFACTURING AND THE WHOLE ECONOMY

Table 2 shows estimates of GDP per employee for the whole economy based on figures derived from Maddison.[16] These estimates were obtained using time series on real GDP and employment for each country, with a benchmark estimate of comparative levels of GDP per worker based on 1985 PPPs. Maddison used bilateral "Paasche"-type PPPs of national currencies compared with U.S. dollars, so he obtained comparisons in terms of U.S.-relative prices. These figures, shown on the left in Table 2, provide the quantitative basis of the conventional chronology of long-run comparative productivity performance outlined earlier; the United States is seen as overtaking Britain as the labor productivity leader in the early 1890s, forging ahead to a substantial lead by 1950, and dropping back to close the gap from 1950 to the 1980s. Germany is seen as coming from a labor productivity level of less than half the British level in 1870 to enjoy a small lead over Britain by the 1970s. Labor productivity levels in all three economies are seen as fairly

[14] Maddison, *Dynamic Forces*, pp. 270–71.
[15] van Ark, "Comparative Levels of Manufacturing," pp. 370–71.
[16] Maddison, *Dynamic Forces*.

close by 1987, particularly in comparison with the position in 1950. Thus, the Maddison figures are usually seen as consistent with the idea of convergence of labor productivity levels among the major industrialized countries.[17]

Note, however, that the use of bilateral Paasche-type PPPs exaggerates the convergence process. If, in the U.S./U.K. comparison, for example, the United States is relatively good at producing cars and the United Kingdom relatively bad, the relative price of cars will tend to be low in the former and high in the latter. Thus, if output is valued at U.S. prices, the high volume of U.S. cars has a low value. However, if output is valued at U.K. prices, the high volume of U.S. cars will have a high value. One common approach to the problem is to take the geometric mean of output valued at U.S. and U.K. prices. Thus Table 2 also shows an adjustment to the Maddison figures using bilateral "Fisher"-type PPPs. Note that this has the effect of substantially raising the level of productivity in the United States relative to Britain and Germany. In particular, with the Fisher-type PPPs the United States was already the labor productivity leader by 1870.

Comparing levels of GDP per worker from Table 2 with the levels of manufacturing output per worker from Table 1 reveals a number of striking differences. First, at the cross-sectional level, labor productivity gaps are always very different in manufacturing from those for the whole economy. In general, British performance is far worse in manufacturing than in the whole economy. Second, the time series reveal rather different patterns. For the whole economy, the United States comes from behind, overtakes Britain, and builds up a substantial lead that is then eroded starting in 1950. Germany, in contrast, comes from having labor productivity levels less than half the British level to take a slight lead by the 1970s. For the manufacturing sector, however, the U.S. lead over Britain has remained two-to-one over the whole period, albeit with substantial fluctuations over sustained periods of a decade or more. Similarly, over the period as a whole there is little trend in the Germany/U.K.–relative labor productivity position in manufacturing, but again substantial fluctuations over sustained periods. Thus the issue of the reconciliation of this evidence from manufacturing and the whole economy should now be addressed.

Cross-Sectional Evidence

British labor productivity performance over the whole period from 1870 on has been substantially worse in manufacturing than in the whole economy. This applies to comparisons with both the United States and Germany and raises questions about the compatibility of the manufac-

[17] Baumol, "Productivity Growth."

TABLE 3
U.S./U.K. GDP PER EMPLOYEE BY MAJOR SECTOR (U.K. = 100)

Sector	1937/35	1950
Agriculture	103	207
Extractive and utilities	316	689
Manufacturing	215	273
Construction	115	150
Transport and communications	282	323
Distribution	150	178
Services, including finance, public and professional	132	122
GDP	173	193

Sources: For 1937/35, Rostas, *Comparative Productivity*, with weights from Matthews, Feinstein, and Odling-Smee, *British Economic Growth*; for 1950, Paige and Bombach, *A Comparison*.

turing and whole-economy estimates. Charles Feinstein, for example, referring to the work of A. D. Smith, David Hitchens, and Stephen Davies, used the whole-economy estimates to suggest that "the true gap in manufacturing . . . must be smaller than these 'industry of origin' calculations suggest."[18] In fact, the two sets of estimates need not be inconsistent.

Paige and Bombach as well as Rostas worked up to estimates of comparative labor productivity for the whole economy on an industry-of-origin basis for the United States and the United Kingdom.[19] Their results for 1950 and 1937/35, respectively, suggest that the manufacturing and GDP estimates can be reconciled. Referring to Table 3 we see that for 1950, the productivity ratio of 273 for manufacturing is consistent with a substantially lower ratio of 193 for GDP, because the American superiority was much smaller in the other sectors—particularly agriculture, construction, distribution, and services. A similar picture emerges from Rostas's estimates for major sectors in the United States (in 1937) compared with the United Kingdom (in 1935).

However, in some of the noncommodity sectors in which output is not marketed (such as public administration, education, health, defense, and research) price information does not exist, so the relative real output between countries is estimated on the basis of relative employment. Hence comparative output per employee is equal to 100 by construction. For the Paige and Bombach study, about 25 percent of GDP is affected in this way (although this is not apparent from the table because of the level of aggregation). Thus it is possible that the comparisons using GDP per worker understate the productivity gap, rather than that the manufacturing estimates overstate it. Recent work

[18] Feinstein, "Economic Growth," p. 3; and Smith, Hitchens, and Davies, *International Industrial Productivity*.

[19] Paige and Bombach, *A Comparison of National Output*; and Rostas, *Comparative Productivity*.

on the measurement of real output in services suggests that progress can be made in this area.[20]

Time-Series Evidence

As well as a substantial difference in the level of comparative labor productivity between manufacturing and the whole economy at any point in time, however, there are very different trends over time. For these different trends to be reconcilable, either trends in other sectors must offset the trends in manufacturing or the expansion and contraction in relative importance of sectors must have had substantial composition effects on overall labor productivity. In fact, both seem likely. Both effects can be seen at work in explaining the single biggest discrepancy between the manufacturing and GDP trends.[21] In manufacturing, U.S. labor productivity was substantially higher than Britain's throughout the nineteenth century, whereas for the whole economy, it rose to leadership only in the 1890s. This rise depended on the settling of the prairies and transport improvements outside of manufacturing, and also on the growth in the relative size of U.S. manufacturing from about 3 percent of employment in 1810 to nearly 20 percent by 1900.[22]

The catching-up by Germany and other European countries to British levels of GDP per worker since the late nineteenth century has been accompanied by a reduction in the share of economic activity accounted for by agriculture. Indeed, Rolf Dumke found the share of the labor force in agriculture to be a highly significant variable in regressions explaining growth in a cross section of countries for the postwar period.[23] He concluded that the shift out of agriculture, which was already a very small sector in Britain by the late nineteenth century, was a very important part of the catching-up process in Europe. This view can also be found in Nicholas Kaldor's explanation of slow productivity growth in postwar Britain as a result of "premature maturity," and in Edward Denison's assessment of the contribution of agricultural contraction to differences in growth rates in nine western countries.[24]

[20] Pilat, "Levels of Real Output"; and Levitt and Joyce, *The Growth and Efficiency.*

[21] Broadberry, "Comparative Productivity."

[22] Lee and Passell, *A New Economic View*, pp. 266–306; and Lebergott, *The Americans*, pp. 268–96, and "Labor Force," p. 119.

[23] Dumke, "Reassessing the *Wirtschaftswunder*," p. 480.

[24] Kaldor, "Causes of the Slow Rate"; and Denison, *Why Growth Rates Differ*. However, before reaching the conclusion that all discrepancies can be swept away, note that for the United States and the United Kingdom, the post-1950 time series for real output are based on production census net output deflated by a price index for manufactures. These series have been preferred to alternative series produced for the national accounts. The problem is that in disaggregating GDP, the national accounts in the United States and the United Kingdom use rather different methods, and for international comparisons we require standardized series. However, rejection of the national accounts series for real output in manufacturing does not imply rejection of the national accounts aggregates built up from the expenditure side. It is simply that within each country the

PROBLEMS FOR THE CONVERGENCE HYPOTHESIS?

Most authors conclude that there has been a convergence of GDP per worker among the major industrialized countries since 1870.[25] This is usually explained in terms of technology transfer in manufacturing.[26] Within manufacturing, however, there is a persistent large labor productivity gap between the United States on the one hand and Britain and Germany on the other. Nevertheless, periods of one country altering its comparative labor productivity position are generally followed by periods of catching-up, restoring the long-run comparative position.

If, as I have argued in this article, the results for manufacturing are consistent with the results for the whole economy, the global convergence of GDP per worker cannot be explained in terms of technology transfer in manufacturing. This in turn suggests the need for a more general view of the catching-up process. In addition to composition effects through structural change, productivity trends in sectors other than manufacturing have a role to play, which suggests a more general view of how following countries borrow from the leader in the process of catching up. Feinstein argues that borrowing from the leader can occur across a wide range of activities, including "property rights and legal procedures, corporate structures and management hierarchies, banking systems and intermediate sources of finance, forms of taxation and of insurance, industrial relations and personnel management."[27]

THE ROLE OF CAPITAL

Much of the literature on Anglo-American comparisons has suggested that at least part of the difference in labor productivity levels between the two countries has been due to the use of more capital per worker in the United States.[28] Hence it is of some interest to calculate comparative levels of total factor productivity (TFP) as well as labor productivity.

Comparative TFP levels for two countries can be calculated as the geometric weighted average of comparative capital productivity and comparative labor productivity, according to the formula

$$\frac{TFP^*}{TFP} = \left(\frac{Y^* / K^*}{Y / K}\right)^{\alpha} \left(\frac{Y^* / L^*}{Y / L}\right)^{1-\alpha} \qquad (1)$$

aggregate has been decomposed in different ways on the output side. Further details are available in Broadberry, "Manufacturing and the Convergence Hypothesis," pp. 11–13.

[25] Abramovitz, "Catching Up"; Baumol, "Productivity Growth"; De Long, "Productivity Growth"; Baumol and Wolff, "Productivity Growth"; Dowrick and Nguyen, "OECD Comparative Economic Growth"; and Wolff, "Capital Formation."

[26] Gomulka, *Inventive Activity*; Cornwall, *Modern Capitalism*; and Nelson and Wright, "The Erosion."

[27] Feinstein, "Benefits of Backwardness," p. 290.

[28] Habakkuk, *American and British Technology*; Rostas, *Comparative Productivity*; Frankel, *British and American Manufacturing*; and Davies and Caves, *Britain's Productivity Gap*.

where Y is output, L employment, and K the capital stock. Variables relating to the United States are indicated by an asterisk. The weights are given by the shares of capital and labor in net output. The share of wages in net output $(1 - \alpha)$ is 0.77, which is the geometric mean of U.S. and U.K. shares for 1975.[29] Equation 1 can be written alternatively as the ratio between comparative output levels and comparative total factor input (TFI):

$$\frac{TFP^*}{TFP} = \frac{Y^* / Y}{(K^* / K)^{\alpha} (L^* / L)^{1-\alpha}} = \frac{Y^* / Y}{TFI^* / TFI} \tag{2}$$

The benchmark level of U.S./U.K. comparative TFP can be established for 1975 using data from van Ark.[30] Post-1950 gross capital stock series in manufacturing are available from the U.S. and U.K. national accounts. Gross capital stock series before 1950 were taken from Feinstein for Britain and from John Kendrick for the United States.[31]

The results, using the official estimates of the capital stock for the postwar period, are shown in the first panel of Table 4. From 1880 onward, the TFP results are more favorable to the United Kingdom than are the labor productivity results. Prior to that date, however, the capital stock estimates suggest greater capital per worker in Britain, so that the TFP results are more favorable to America.

Van Ark also presented some figures on standardized capital stock estimates for the postwar period, which are used in the second panel of Table 4.[32] The official capital stock estimates are based on very different assumptions about asset lives in the two countries. For nonresidential buildings, asset lives are assumed to be 60 years in the United Kingdom and 25 years in the United States. For industrial equipment, asset lives are assumed to be 25 and 19 years, respectively. Because the capital stock estimates are obtained by cumulating investments and allowing for retirements, these assumptions tend to result in a large U.K. capital stock for relatively little investment and a small U.S. capital stock despite relatively high investment. Given that very little is actually known about asset lives, it is also useful to calculate standardized capital stocks, applying the same asset life assumptions to both countries. Van Ark calculates standardized capital stocks for Britain and America based on common asset life assumptions of 45 years for structures and 20 years for equipment.[33] These assumptions lead to the conclusion that capital per worker was substantially greater in the United States during the postwar period, so that the TFP gap between

[29] van Ark, "Comparative Levels of Manufacturing," pp. 355–56.
[30] Ibid., p. 354.
[31] Feinstein, *National Income* and "Sources and Methods"; and Kendrick, *Productivity Trends*.
[32] van Ark, "Comparative Levels of Manufacturing," p. 367.
[33] Ibid., p. 353.

TABLE 4
COMPARATIVE U.S./U.K. LEVELS OF LABOR PRODUCTIVITY, TOTAL FACTOR PRODUCTIVITY, AND CAPITAL PER WORKER IN MANUFACTURING (U.K. = 100)

Year	Output/Employment	Capital Stock/ Employment	Total Factor Productivity
	Official Capital Stock Data		
1869	203.8	93.7	204.9
1879	187.8	91.8	189.7
1889	195.5	159.0	174.0
1899	194.8	188.2	166.8
1909	208.5	183.0	179.7
1919	206.9	178.1	179.5
1929	249.9	173.1	218.2
1937	208.3	151.2	187.7
1950	262.6	155.2	235.1
1958	250.0	165.1	220.7
1968	242.7	133.1	225.1
1975	207.5	142.1	189.2
1980	192.9	120.7	183.0
1984	183.3	110.5	177.5
1987	188.8	109.9	183.1
	Standardized Capital Stock Data		
1950	262.6	251.3	199.1
1958	250.0	264.1	187.4
1968	242.7	202.7	193.3
1975	207.5	206.6	166.6
1980	192.9	174.4	159.0
1984	183.3	166.7	152.7
1987	188.8	172.8	156.1

Sources: For the basic series, see Appendix Tables 1 and 2. The standardized estimates are from van Ark, "Comparative Levels of Manufacturing."

it and Britain was substantially narrower than the labor productivity gap.

However, the prewar estimates of capital are based much more heavily on stock data than on cumulated investments, so that similar calculations of standardized capital stocks would be inappropriate.[34] Thus it seems likely that the finding of greater output per worker in the United States but greater capital per worker in the United Kingdom during the nineteenth century is not a statistical artifact. Alex Field explains this apparent paradox by higher American interest/profit rates (due to land abundance), which led to the choice of "shorter-lived capital goods, faster operational speeds, and organizational forms that economize on inventory stocks."[35] An alternative explanation might distinguish between skilled and unskilled manufacturing, with only the

[34] Creamer, *Capital and Output Trends*; and Feinstein, "Sources and Methods."
[35] Field, "Land Abundance," p. 408.

TABLE 5
COMPARATIVE GERMANY/U.K. LEVELS OF LABOR PRODUCTIVITY, TOTAL FACTOR PRODUCTIVITY, AND CAPITAL PER WORKER IN MANUFACTURING
(U.K. = 100)

Year	Output/Employment	Capital Stock/ Employment	Total Factor Productivity
1875	100.0	60.4	116.4
1882	83.6	58.8	98.1
1889	94.7	71.2	104.9
1899	99.0	97.6	99.8
1909	117.7	98.0	118.5
1913	119.0	105.3	117.2
1925	95.2	61.0	110.5
1929	104.7	67.1	118.0
1937	99.9	73.2	109.8
1950	96.0	77.8	103.6
1958	111.1	71.5	122.8
1968	120.0	95.3	121.8
1975	132.9	107.2	130.2
1980	140.2	92.7	143.5
1984	122.7	81.2	130.7
1987	107.8	76.4	116.9

Source: See Appendix Tables 1 and 2.

former being more capital intensive in the United States, and the United Kingdom having greater capital intensity in manufacturing as a whole.[36]

Repeating the TFP calculations for the Germany/U.K. comparison using the official capital stock estimates (see Table 5), again physical capital does not at first sight play a major role in explaining labor productivity differences. However, Mary O'Mahony shows that standardizing the asset lives between the two countries implies that capital per worker in Germany was 127.3 percent of the British level in 1987 rather than 76.4 percent, as in Table 5.[37] But again it would be inappropriate to standardize the prewar estimates, which are based largely on stock data.

Finally, even if we accept that the standard growth-accounting framework gives too small a weight to capital, a large portion of the labor productivity level differences identified in this article remains unexplained by capital. The standard Solow approach weights capital by its share in income, which is usually about 0.3.[38] However, even if Paul Romer's extreme case of constant returns to capital were accepted and capital given a weight of unity, this would not help reconcile the nineteenth-century finding of higher labor productivity in the United States and higher capital intensity in Britain.[39]

[36] James and Skinner, "The Resolution."
[37] O'Mahony, "Productivity Levels," p. 53.
[38] Solow, "Technical Change."
[39] Romer, "Increasing Returns."

TECHNOLOGICAL CHOICE AND PRODUCTIVITY ESTIMATES BY MANUFACTURING BRANCH

For the nineteenth century, there is an extensive literature linking the U.S. productivity advantage in manufacturing to technological choice through resource endowments. H. J. Habakkuk's development of Erwin Rothbarth's thesis suggested that land abundance and labor scarcity in America led to high relative wages and the substitution of capital for labor.[40] However, we have seen that capital per worker was greater in Britain, so the simplest form of the Habakkuk thesis cannot be correct. A more subtle formulation by Edward Ames and Nathan Rosenberg argued that American firms substituted cheap resources and resource-using machinery for skilled labor, thus emphasizing the complementarity between machinery and resources.[41] This substitution raised output per worker in America as firms moved toward standardized mass production. British and German firms could not initially adopt machinery that was very wasteful of resources, so they continued to compete on the basis of skilled labor. The wood lathe is the classic early example: it could not be adopted in Europe, where wood costs were much higher. Note that the Ames and Rosenberg formulation is quite consistent with the finding of higher capital per worker in Britain because machinery forms only a small part of the capital stock, which is dominated by structures.[42]

However, American mass production techniques could not be successfully applied at the same time in all industries. For example, in shipbuilding it was only in the 1950s, with the perfection of welding and prefabrication techniques, that mass production could become widespread. Furthermore, European firms' decision to not immediately adopt American technology was perfectly consistent with rational behavior, given their different resource endowments and relative factor prices. Indeed, many studies document the rationality of the response of British entrepreneurs to the American innovations of the late nineteenth century.[43] Often the new American technologies improved over time or had to be adapted to local circumstances before they became profitable. In some cases British firms were able to compete successfully for some time with incremental improvements in British technology, raising productivity and offsetting improvements in American technology.[44] In other cases, as the American techniques improved British firms were

[40] Habakkuk, *American and British Technology*; and Rothbarth, "Causes of the Superior Efficiency."

[41] Ames and Rosenberg, "The Enfield Arsenal."

[42] Field, "On the Unimportance of Machinery."

[43] McCloskey, *Economic Maturity*; Harley, "Skilled Labour"; and Sandberg, *Lancashire in Decline*.

[44] Sandberg, *Lancashire in Decline*; Lorenz and Wilkinson, "The Shipbuilding Industry."

TABLE 6
U.S./U.K. MANUFACTURING OUTPUT PER EMPLOYEE (U.K. = 100)

Industry	1909/07	1937/35	1950	1967/68	1975	1987
Chemicals and allied products	156.4	226.9	356.4	281	226.8	152.4
Basic metals	288.0	192.0	274.4	261	251.1	166.2
Engineering, including metal products	202.3	289.1	337.3	294	190.6	185.8
Textiles, leather, and clothing	150.7	145.4	197.9	225	222.8	174.0
Food, drink, and tobacco	137.2	203.5	215.3	246	208.4	232.9
Other, including wood, paper, and stone	227.2	210.8	284.7	276	274.8	207.5
Total manufacturing	208.5	217.9	273.4	276	224.7	186.6

Note: In 1975 and 1987 columns, metal products are included with basic metals.
Sources: For 1909/07, Broadberry, "Comparative Productivity"; for 1937/35, Rostas, *Comparative Productivity*; for 1950, Paige and Bombach, *A Comparison*; for 1967/68, Smith, Hitchens, and Davies, *International Industrial Productivity*; for 1975, van Ark, "Comparative Levels of Manufacturing"; for 1987, van Ark, "Comparative Productivity in British."

forced at some point to switch to more American methods of production.[45]

We should expect comparative productivity ratios to vary by industry and these patterns of comparative productivity to change over time. The figures by manufacturing branch shown in Tables 6 and 7 can be interpreted in the light of the competition between technologies just discussed. In textiles, for example, British craft production methods with skilled labor continued to compete effectively with American methods before World War II, whereas from 1950, Britain's comparative productivity position in textiles converged toward the position for aggregate manufacturing.

The other sector in which British productivity performance was relatively good before World War II was food, drink, and tobacco.[46] This is an interesting case, in that in these process industries Britain was quick to develop large-scale production catering to standardized demand along American lines.[47] This shows up clearly in the comparative productivity figures for the first half of the twentieth century, in both the U.S./U.K. and Germany/U.K. comparisons.

Turning to the heavier industries, the comparative productivity picture in engineering appears to have been dominated by sectors such as motor vehicles. There, a large American productivity lead developed on the basis of mass production techniques in the first half of the nineteenth century, but British firms continued to compete on the basis of skilled labor. The adaptation of American multinationals in motor

[45] Lewchuk, *American Technology*.
[46] Broadberry and Crafts, "Explaining Anglo-American," pp. 396–97.
[47] Jefferys, *Retail Trading*; Mathias, *Retailing Revolution*; Vaizey, *The Brewing Industry*; and Alford, *W. D. and H. O. Wills*.

TABLE 7
GERMANY/U.K. MANUFACTURING OUTPUT PER EMPLOYEE (U.K. = 100)

Industry	1935	1967/68	1987
Chemicals and allied products	122.9	124.0	88.5
Basic metals	116.0	136.7	96.1
Engineering, including metal products	119.7	116.8	111.6
Textiles, leather, and clothing	97.2	107.9	109.0
Food, drink, and tobacco	41.3	94.2	114.1
Other, including wood, paper, and stone	101.8	140.6	131.6
Total manufacturing	102.0	118.9	112.7

Sources: For 1935, Broadberry and Fremdling, "Comparative Productivity"; for 1967/68, Smith, Hitchens, and Davies, *International Industrial Productivity*; for 1987, O'Mahony, "Productivity Levels."

vehicles to European conditions confirms the rationality of different strategies of technological choice on both sides of the Atlantic.[48] British firms' eventual switch to a more American style of production from the late 1960s meant a convergence of relative productivity in engineering toward the figures for aggregate manufacturing. However, even within engineering the picture was not uniform; as already noted, in shipbuilding mass production techniques did not become dominant until the 1950s, and Britain continued to compete effectively on the basis of skilled labor until then.

Comparative productivity trends in chemicals and basic metals are similar to trends in engineering, with a recent improvement in British performance removing a long-standing above-average productivity gap in those sectors.

A number of authors have suggested that other factors besides resources and technological choice contributed to the U.S. productivity lead. Rostas, Marvin Frankel, and Alfred Chandler, among others, stressed the larger market size in America, which allowed longer production runs.[49] One of the difficulties with this argument is that the large U.S. productivity lead in manufacturing goes back to the mid-nineteenth century, when U.S. population was not substantially larger than in Britain.[50] However, Richard Nelson and Gavin Wright argued that the basis of the American productivity lead may have changed over time—recently having more to do with research and development than with resources.[51]

[48] Foreman-Peck, "The American Challenge."

[49] Frankel, *British and American Manufacturing*; Rostas, *Comparative Productivity*; and Chandler, *Scale and Scope*.

[50] Maddison, *Dynamic Forces*, pp. 226–27.

[51] Nelson and Wright, "The Rise and Fall."

The R&D argument does seem to be a promising way of integrating human capital into the explanation of productivity differences along the lines suggested by recent work on growth theory.[52] This is particularly noteworthy given the reliance of European countries on skilled labor, the other common way of measuring human capital.[53]

CONCLUDING COMMENTS

This article suggests that the commonly accepted chronology for comparative labor productivity levels, based on GDP data, does not apply to the manufacturing sector. Despite substantial swings in comparative labor productivity for periods of a decade or so in manufacturing, over the long run there is evidence of a much greater degree of stationarity of comparative labor productivity performance. In particular, the United States has continued to enjoy a substantial labor productivity lead over Britain and Germany. This cannot be explained simply by differences in capital intensity, because the lead is also reflected in differences in TFP. Rather, it appears that technological choice is responsible for the large U.S./Europe productivity gap. Branch level estimates are consistent with this view. These results for manufacturing suggest that convergence of GDP per worker must have occurred through trends in other sectors and through compositional effects of structural change.

[52] Romer, "Human Capital and Growth."
[53] Prais, "Qualified Manpower."

Appendices

APPENDIX TABLE 1
REAL OUTPUT AND EMPLOYMENT IN MANUFACTURING (1929 = 100)

	United Kingdom		United States		Germany	
Year	Output	Employment	Output	Employment	Output	Employment
1869	29.3	66.9	7.1	19.9	—	—
1870	31.8	68.8	—	—	16.3	—
1871	34.6	70.8	—	—	18.2	—
1872	35.4	71.7	—	—	20.9	—
1873	36.2	72.1	—	—	21.8	—
1874	37.0	72.2	—	—	22.2	—
1875	36.5	72.3	—	—	22.0	45.6
1876	36.6	71.8	—	—	22.3	—
1877	37.4	71.5	—	—	22.0	—
1878	36.6	70.5	—	—	22.7	—
1879	34.5	67.6	10.2	26.6	23.0	—
1880	40.1	72.3	—	—	22.3	—
1881	41.6	74.1	—	—	23.4	—
1882	44.3	75.9	—	—	23.3	50.0
1883	44.6	76.6	—	—	25.0	—

APPENDIX TABLE 1—continued

Year	United Kingdom		United States		Germany	
	Output	Employment	Output	Employment	Output	Employment
1884	42.4	73.0	—	—	26.1	—
1885	40.4	72.9	—	—	26.5	52.9
1886	40.1	73.0	—	—	27.0	54.5
1887	43.9	75.9	—	—	28.6	55.8
1888	46.9	79.0	—	—	30.1	57.6
1889	50.3	82.4	18.3	38.3	33.2	60.0
1890	50.7	85.5	19.7	39.9	33.5	62.1
1891	51.2	83.1	20.2	41.1	34.2	61.8
1892	47.9	81.5	21.9	43.6	35.0	61.6
1893	47.8	84.5	19.4	42.1	36.3	61.7
1894	49.4	82.4	18.8	40.0	38.4	62.3
1895	52.5	84.1	22.4	43.6	41.5	64.1
1896	59.7	86.6	20.4	42.7	43.7	67.3
1897	57.3	87.9	22.0	44.2	44.7	69.9
1898	60.6	89.1	25.1	45.4	47.4	72.3
1899	63.0	90.6	27.5	50.8	48.7	74.1
1900	62.3	90.3	27.7	52.8	48.6	75.9
1901	62.1	90.2	30.9	55.5	48.6	74.8
1902	62.3	90.4	35.5	60.4	49.6	74.5
1903	60.8	90.9	35.4	62.7	53.0	76.0
1904	61.2	90.4	34.2	59.1	55.2	78.0
1905	66.5	92.1	39.0	66.1	57.6	80.0
1906	69.6	94.3	41.6	69.6	59.7	82.2
1907	71.5	95.0	42.1	72.8	64.1	83.7
1908	65.4	91.6	33.7	65.2	64.8	82.4
1909	66.2	92.4	43.4	72.7	66.3	82.4
1910	66.9	96.2	45.1	76.0	68.9	84.9
1911	72.6	98.6	42.7	76.0	73.1	87.1
1912	75.6	99.6	51.3	79.4	78.6	89.5
1913	80.5	102.2	53.8	80.2	80.9	90.4
1914	75.0	—	51.1	77.4	—	—
1915	78.9	—	59.9	80.9	—	—
1916	73.9	—	71.2	95.4	—	—
1917	68.4	—	70.6	102.0	—	—
1918	66.4	—	69.8	104.0	—	—
1919	74.3	—	61.0	100.3	—	—
1920	81.7	110.5	66.0	100.1	—	—
1921	63.6	86.9	53.5	77.4	—	—
1922	74.0	90.9	68.1	84.7	—	—
1923	79.3	93.3	76.9	96.2	—	—
1924	87.3	94.9	73.4	90.2	—	—
1925	90.0	95.5	81.9	92.7	84.7	98.8
1926	87.1	92.8	86.2	94.7	75.9	87.0
1927	96.3	98.7	87.1	93.5	97.3	100.8
1928	96.1	98.6	90.1	93.8	98.4	103.6
1929	100.0	100.0	100.0	100.0	100.0	100.0
1930	95.7	93.0	85.6	89.2	88.4	90.3
1931	89.2	86.8	72.0	75.6	74.0	77.1
1932	89.7	88.1	53.8	63.9	64.5	65.8
1933	96.3	91.4	62.8	98.9	71.0	70.1
1934	105.1	95.6	69.1	79.9	85.6	81.9
1935	114.6	97.9	82.8	85.1	102.3	89.7
1936	125.3	103.3	96.8	92.2	112.9	96.7

Appendix table 1—continued

Year	United Kingdom Output	United Kingdom Employment	United States Output	United States Employment	Germany Output	Germany Employment
1937	132.9	108.5	103.3	101.2	122.3	104.6
1938	129.0	106.9	80.9	87.4	136.3	110.4
1939	—	—	102.5	95.5	—	—
1940	—	—	118.6	104.3	—	—
1941	—	—	157.9	125.7	—	—
1942	—	—	197.2	146.1	—	—
1943	—	—	238.1	166.3	—	—
1944	—	—	232.5	163.1	—	—
1945	—	—	196.5	145.5	—	—
1946	135.0	—	160.6	139.1	—	—
1947	142.8	—	178.3	145.9	—	—
1948	155.7	127.2	184.2	146.5	—	—
1949	165.7	129.5	173.5	136.1	—	—
1950	177.1	132.8	201.1	143.5	77.8	63.6
1951	184.0	144.5	206.2	151.9	89.7	71.3
1952	183.3	141.6	225.5	156.0	101.5	73.8
1953	201.2	142.9	251.6	166.1	113.2	76.9
1954	222.4	146.0	240.1	156.7	126.7	81.6
1955	234.4	150.5	273.9	163.4	148.3	89.3
1956	237.4	150.5	282.9	166.9	160.0	95.4
1957	242.4	151.4	279.9	166.2	170.9	98.7
1958	252.1	148.1	265.2	155.7	179.9	99.6
1959	270.6	148.4	300.2	161.9	196.9	100.7
1960	296.4	154.3	304.2	162.9	223.2	106.0
1961	301.0	156.0	306.0	158.7	235.9	109.1
1962	306.2	153.8	333.2	162.9	246.3	109.6
1963	321.5	151.4	358.1	164.8	249.5	108.9
1964	350.7	153.5	382.5	167.8	273.5	108.9
1965	360.7	155.0	414.0	175.0	293.7	110.8
1966	367.0	155.0	445.1	184.8	296.5	109.6
1967	369.4	150.2	460.5	187.7	287.6	103.7
1968	395.1	149.0	488.7	189.7	317.7	104.5
1969	419.3	152.1	503.9	194.7	356.2	108.9
1970	430.3	152.9	478.8	186.7	373.1	111.4
1971	422.8	149.0	485.2	178.4	376.4	110.6
1972	443.5	143.1	527.7	184.9	388.2	108.6
1973	482.4	145.0	551.8	192.8	412.1	109.3
1974	485.8	147.6	516.1	192.8	409.8	106.8
1975	437.5	142.1	454.6	177.8	391.9	100.2
1976	448.6	139.0	502.5	182.2	422.9	98.0
1977	428.7	138.6	541.0	190.3	431.9	98.3
1978	439.0	135.3	545.0	199.2	439.4	98.2
1979	457.1	131.9	574.2	204.4	461.5	99.4
1980	416.9	124.1	520.1	200.6	451.1	100.2
1981	392.6	110.4	514.7	196.9	448.3	98.3
1982	386.0	102.4	494.9	185.5	431.9	95.5
1983	395.4	97.0	524.3	181.8	438.4	92.3
1984	404.7	96.7	570.5	185.8	451.1	91.9
1985	412.2	95.1	577.7	182.6	468.5	93.0
1986	419.7	93.2	611.4	178.5	472.3	94.6
1987	448.8	93.1	670.5	184.1	469.9	94.6
1988	477.9	94.2	694.8	186.0	484.5	94.5
1989	496.2	94.6	687.2	185.0	504.7	95.9

UNITED KINGDOM SOURCES

Output

1869–1950: Feinstein, *National Income*, table 51.
1950–1989: Census of Production, net output deflated by producer price index for manufacturing from *Annual Abstract of Statistics*. For the period 1950 to 1970, I interpolated onto an annual basis using the industrial production index from the national accounts.

Employment

1869–1950: Feinstein, *National Income*, tables 59, 60. I adjusted for the exclusion of southern Ireland from 1920, using an estimate of employment in manufacturing in the Irish Republic in 1926 from Mitchell, *British Historical Statistics*, p. 110. Before 1920, annual estimates were obtained by interpolation using the series on civil employment from Feinstein, *National Income*, table 57.
1950–1989: Census of Production. For the period 1950 to 1970, I obtained annual estimates by interpolation using employment data from Feinstein, *National Income*, table 57; *British Labour Statistics Historical Abstract*; and *British Labour Statistics Yearbook*, 1976.

UNITED STATES SOURCES

Output

1869–1950: Kendrick, *Productivity Trends*, table D-II.
1950–1989: Census of Manufactures, net output (census value added) deflated by producer price index for manufacturing produced by the Bureau of Labor Statistics.

Employment

1869–1950: Kendrick, *Productivity Trends*, table D-II.
1950–1989: Census of Manufactures, *Annual Survey of Manufactures*.

GERMANY SOURCES

Output

1869–1950: Hoffmann, *Das Wachstum*, table 76, reweighted to exclude construction and gas, water, and electricity.
1950–1989: *Volkswirtschaftliche Gesamtrechnungen Fachserie 18, Reihe S.15, Revidierte Ergebnisse, 1950 bis 1990*, Statistisches Bundesamt, 1991.

Employment

1869–1950: Hoffmann, *Das Wachstum*, table 15, excluding construction and gas, water and electricity.
1950–1960: *Lange Reihen zur Wirtschaftsentwicklung*, 1988.
1960–1989: *Volkswirtschaftliche Gesamtrechnungen, Fachserie 18, Reihe S.15, Revidierte Ergebnisse, 1950 bis 1990*, Statistisches Bundesamt, 1991.

APPENDIX TABLE 2
GROSS REPRODUCIBLE CAPITAL STOCK AT CONSTANT REPLACEMENT COST IN MANUFACTURING (1929 = 100)

Year	United Kingdom	United States	Germany
1869	27.0	4.4	—
1875	32.3	—	18.4
1879	36.3	7.6	—
1882	38.4	—	22.2
1889	41.2	17.6	31.9
1899	48.1	29.3	57.2
1909	65.4	54.4	85.1
1913	72.6	—	100.8
1919	91.0	92.9	—
1925	97.7	—	91.8
1929	100.0	100.0	100.0
1937	104.8	85.4	110.2
1950	140.8	136.5	78.2
1958	184.4	185.0	132.2
1968	268.2	262.8	267.1
1975	322.5	344.9	374.6
1980	368.5	415.7	411.3
1984	376.5	461.9	433.3
1987	384.8	483.0	445.7

UNITED KINGDOM SOURCES

1869–1920: Feinstein, "Sources and Methods," table XI.
1920–1950: Feinstein, *National Income*, table 45.
1950–1987: C.S.O., *National Income and Expenditure* (The 'Blue Book').

UNITED STATES SOURCES

1869–1950: Kendrick, *Productivity Trends*, table D-I.
1950–1982: U.S. Department of Commerce, *National Income and Product Accounts.*
1982–1987: *Survey of Current Business.*

GERMANY SOURCES

1875–1959: Hoffmann, *Das Wachstum*, table 39.
1959–1987: Statistisches Bundesamt, *Volkswirtschaftliche Gesamtrechnungen, Fachserie 18, Reihe S.15, Revidierte Ergebnisse, 1950 bis 1990.*

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