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Productivity Levels in Germany, Japan, and the United States: Differences and Causes

THIS PAPER EXPLORES the comparative productivity performance in manufacturing of three countries—Germany, Japan, and the United States—since 1950.[1] The productivity level estimates are based on the industry-of-origin approach, making use of detailed information from censuses of manufactures for each country. Comparative measures of sectoral productivity levels have a vast array of applications in, for example, the study of structural change, technological progress, comparative advantage, and competitiveness and in the analysis of catch-up and convergence.

Since the late nineteenth century the United States has led the world economy in per capita income and productivity.[2] Many countries, in particular those in the Organization for Economic Cooperation and Development (OECD), have converged on the U.S. productivity level since World War II. It has been suggested frequently that the U.S. productivity

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1. "Germany" in this paper refers to the former Federal Republic of Germany.
2. See, for example, Abramovitz (1986); Baumol (1986); and De Long (1988).

advantage has further eroded during the 1980s. Signs have also appeared that the United States might have lost its pioneering role in certain key technological areas during the past decade. Nevertheless, recent estimates of gross domestic product (GDP) per hour worked still show the United States ahead of its most important rivals.[3]

Here we focus on the comparative performance of one major sector of the economy, manufacturing. Despite the decreased importance of manufacturing in advanced countries in shares of output and employment, its role in the economy remains important, because the sector generates most technological innovations with important spillover effects to the rest of the economy. Moreover, the three countries considered in this paper continue to play a major role in world production and trade of manufactured products. In 1988 Germany, Japan, and the United States accounted for as much as 35 percent of trade in manufactured goods among market economies.

This paper shows that the comparative productivity performance in manufacturing reflected the catch-up and convergence process for the economy as a whole for most of the postwar period. Apart from a brief interruption during the early 1980s, the manufacturing productivity gap between Japan and the United States continuously narrowed from 1950 to 1990, the latest year in our comparison. The German manufacturing productivity level relative to the United States also rose—although at a slower pace—during the first three decades after the Second World War, but the productivity gap between the two countries widened during most of the 1980s.

We begin with a brief review of the industry-of-origin method, which we used for our productivity comparisons, and a discussion of the results pertaining to unit value ratios, relative output, and productivity for six major manufacturing branches.[4] The results for 1987, the year on which the comparisons are benchmarked, are then extrapolated over a period of

3. Among a wide range of studies focusing on comparative productivity performance at the level of the total economy, see Baumol, Blackman, and Wolff (1989); and Maddison (1987, 1991), which are particularly informative. For a review of issues concerning American technological leadership, see Lawrence (1984); Baily and Chakrabarty (1988); and Nelson and Wright (1992).

4. The six major branches more or less represent light industries (food, beverages, and tobacco; textiles, clothing, and leather products; other industries), heavy industries (chemicals, petroleum, rubber, and plastic products; basic and fabricated metals) and investment industries (machinery, electrical machinery, and transport equipment).

four decades (1950 to 1990) by national time series on output and labor input. We then look more deeply into some of the factors that account for the productivity gap, such as differences in capital and skill intensity, the composition of the manufacturing sector, and the size distribution of manufacturing plants.

Estimating Comparative Productivity Levels in Manufacturing

The comparisons of sectoral output and productivity levels in this study are based on the industry-of-origin method, which involves comparisons of real output in major sectors of the economy (agriculture, industry, and services) and of branches and industries within these broad sectors. This approach differs from the more widely used expenditure approach to level comparisons, which focuses on the expenditure components of GDP (private consumption, investment, and government expenditure).[5]

In the first industry-of-origin studies, comparisons were frequently made by comparing physical quantities (tons, liters, units) of output of product items.[6] As the number of product items increased and as the number of product varieties rose exponentially, arriving at a satisfactory coverage of output by physical quantity indicators became increasingly difficult. The alternative is to derive a specific conversion factor for each industry to convert the output value of all product items to a common currency.

Since 1983 a substantial research effort has been made at the University of Groningen to develop the industry-of-origin approach as part of the International Comparisons of Output and Productivity (ICOP) project. Most ICOP studies so far deal with comparisons for the man-

5. See the results of the surveys conducted at regular intervals by the International Comparisons Project (ICP) since 1967 (for example, Kravis, Heston, and Summers, 1982) and the subsequent Penn World Tables (Summers and Heston, 1988, 1991), which were derived from the ICP estimates.

6. See, for example, Rostas (1948) on a comparison of manufacturing output and productivity between the United Kingdom and the United States from 1935 to 1939. For an extensive discussion of the alternative methods and procedures and an overview of studies based on the industry-of-origin approach, see van Ark (forthcoming).

ufacturing sector, which now cover seventeen countries.[7] Substantial progress has also been made in measuring comparative productivity performance in other sectors of the economy, including agriculture and services.[8]

The most solid basis for industry-of-origin comparisons is provided when all information for each country can be derived from the same primary source. For manufacturing the best source is the national census of production. It shows considerable detail on the output and input structure by industry as well as information on the sales value and quantities of specific products. For the United States we used the *1987 Census of Manufactures*, which provides information on about 450 industries and 11,000 products.[9] For Germany we made use of the *Kostenstruktur der Unternehmen 1987*, which is based on an annual survey. It includes some 175 industries, but only covers enterprises with twenty or more employees; enterprises with fewer than twenty employees are therefore excluded from our Germany-U.S. comparison. Product detail on Germany for some 6,000 items is taken from the *Produktion im Produzierendes Gewerbe 1987*. The basic source for Japan was the *Census of Manufactures* for 1987, which shows information for about 575 industries in the *Report by Industries* and for about 1,850 product items in the *Report by Commodities*. The latest year for which census or survey information is available in all three countries was 1987. For the adjustments for the hours worked per person, we made use of separate sources.[10]

Unit Value Ratios

Our currency conversion factors are based on unit value ratios (or UVRs)[11] for comparable manufactured product items for two pairs of

7. These countries are Argentina, Australia, Brazil, Czechoslovakia, Ecuador, France, Germany (FRG and GDR), India, Indonesia, Korea, Japan, Mexico, the Netherlands, Spain, the United Kingdom, and the United States. See, for example, Maddison and van Ark (1988); Szirmai and Pilat (1990); and van Ark (1990, forthcoming).

8. See Maddison and Van Ooststroom (1993) for a comparison of agricultural output and productivity for thirteen countries. See Pilat (1993) for a total economy comparison based on sectoral estimates. See Mulder and Maddison (1993) for a detailed account of comparative productivity performance in distribution.

9. For data sources, see data appendix.

10. See appendix and tables A-3 and A-4 for sources.

11. Other studies use the term "purchasing power parity" instead of "unit value

countries: Germany and the United States, and Japan and the United States. UVRs are preferable to official exchange rates. If the latter is used, one implicitly assumes that price levels between countries are the same for any item. Exchange rate conversions are therefore based on the "law of one price" and can be referred to as "nominal" output comparisons. In reality prices of one country can be relatively high for one item and relatively low for another compared with the prices of the other country. These variations are caused by a range of factors related to both demand and supply. For example, the price of factor inputs may differ because of differences in factor mobility or production techniques. Protection or trade barriers may cause a lack of competitiveness in one country compared with the other. Or sectoral demand patterns may differ between countries. Furthermore, the exchange rate itself has been increasingly affected in recent years by capital movements and speculation on the currency markets.

For comparisons of real output, price comparisons are required for separate items. We obtained the unit values from the production censuses by dividing the total ex-factory sales value for reported items by their corresponding quantities and deriving unit value ratios for products that could be matched between countries.

This method is fundamentally different from the specification pricing technique of International Comparison Project expenditure studies. Our unit values have a quantity counterpart, and quantities times prices always equal the value equivalent. There are two ways in which other scholars have used expenditure-based purchasing power parities (PPPs) for sectoral productivity analysis. Some studies have applied expenditure GDP PPPs to sectors.[12] Others have used expenditure PPPs with a specific sectoral content, which we call "proxy PPPs."[13]

Expenditure PPPs are suitable for analyzing real output and productivity at the total economy level, but for sectoral analysis they may lead to considerable biases. First, expenditure-based PPPs include prices of imports, but not of exports.[14] Second, the expenditure prices include

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ratio." These two terms are interchangeable, but the latter term expresses more clearly the nature of our "price" information.

12. Dollar and Wolff (1988; 1993).

13. Hooper and Larin (1989); Jorgenson, Kuroda, and Nishimizu (1992).

14. For Japan several studies have documented the different behavior of domestic and export prices; see, for instance, Ohno (1989); and Marston (1990).

Table 1. Number of Unit Value Ratios, Coverage Percentages, and Unit Value Ratios at Own Country and U.S. Weights by Major Manufacturing Branch, 1987

		Matched sales as a % of total sales		*Unit value ratios (national currency/US$)*		
Branch	*Number of UVRs*	*Own country*	*U.S.*	*Own country quantity weights*	*U.S. quantity weights*	*Geometric average*
Germany/U.S.						
Food, beverages, tobacco	55	47.9	39.0	1.94	2.00	1.97
Textiles, apparel, leather	59	48.5	49.8	2.66	2.82	2.74
Chemicals, allied products	26	13.6	30.5	2.40	2.51	2.45
Basic, fabricated metals	31	46.5	23.9	2.16	2.25	2.20
Machinery, equipment	61	24.9	18.7	2.08	2.04	2.06
Other manufacturing	39	19.8	17.0	2.16	2.35	2.25
Total manufacturing	271	24.4	24.8	2.16	2.25	2.21
Japan/U.S.						
Food, beverages, tobacco	20	19.0	17.9	332.6	308.3	320.2
With double deflation[a]				251.0	234.9	242.8
Textiles, apparel, leather	27	25.1	34.2	181.9	184.7	183.3
Chemicals, allied products	43	20.7	31.9	173.8	217.6	194.4
Basic, fabricated metals	34	24.9	22.9	164.4	193.7	178.4
Machinery, equipment	45	17.1	16.1	108.7	158.4	131.2
Other manufacturing	21	15.9	11.3	196.9	237.8	216.4
Total manufacturing	190	19.1	19.9	150.7	212.2	178.8
With double deflation for food[a]	...	...	...	148.5	202.9	173.6

Source: See tables A-1 and A-2.

a. Double deflation for food products was calculated by applying a UVR for agricultural inputs for 1985 derived from Prasada Rao (1993) extrapolated to 1987.

trade and transport margins, which may differ between countries. For example, the inefficient Japanese distribution system leads to relatively high distribution margins in Japan and therefore to a substantial bias in a comparison with the United States. Third, expenditure-based PPPs exclude price ratios for intermediate products, which form a substantial part of manufacturing output. Applying GDP PPPs to sectoral analysis leads to an additional problem, because these PPPs are not just based on products with a substantial manufactured content, but also represent relative prices of various other products, many of which are non-tradable.

The price comparisons underlying our own calculations could not be obtained for all product items. First, the description of the products in the production censuses often differed. For example, the production of bricks may be specified in cubic meters in one country and in tons in the other country. In some cases, expert information from industry sources provided a way out of these problems, but in other instances the product match could not be made. Second, the censuses do not report on sales values or quantities for some products, generally because to do so would breach confidentiality. Third, certain products have a unique character and are produced only in one country and not in the other (for example, supertankers in Japan and space aircraft in the United States). Fourth, and probably most important, many products cannot be matched because they represent different qualities in terms of product mix or content.

Table 1 shows that we obtained 271 unit value ratios for the Germany-U.S. comparison, which are based on 24.4 percent of total manufacturing shipments in Germany and 24.8 percent in the United States. Coverage was slightly lower in the Japan-U.S. comparison, for which we made 190 matches covering 19 to 20 percent of manufacturing sales.

Mainly because of differences in product mix and product quality, our coverage percentages are relatively low in branches such as machinery and transport equipment. Recently, the McKinsey Global Institute scrutinized our UVRs for nine industries (audio and video equipment, beer, computers, food products, iron and steel, machine tools, passenger cars, car parts, and soap and detergents) to assess the extent to which differences in product mix and product quality affected the comparisons. For three industries (computers, machine tools, and motor vehicles) substantial adjustments were made to the original product UVRs we use here, but the assessment found no clear evidence of a systematic bias in our UVRs across industries.[15] In branches that include products with fewer quality and mix differences between countries (for example, textiles, paper and wood products, nonmetallic min-

15. McKinsey Global Institute (1993). For example, in the comparison between Japan and the United States, our UVR for passenger cars was adjusted upward to allow for the smaller size of Japanese cars, but that adjustment was partly offset by an adjustment for the better quality of Japanese cars. McKinsey also obtained substantially different industry PPPs for food products, but these were derived from ICP expenditure PPPs adjusted for distribution margins and indirect taxes rather than taken directly from the census.

erals, and basic metals), the margin of uncertainty of our UVRs is much smaller. These branches represent one third to half of manufacturing output in all three countries. On the whole we judge our UVRs to be sufficiently robust at the level of the six major manufacturing branches, which we analyze below.[16]

Because it was impossible to match all product items in manufacturing, a method was required to fill the holes for the 75 to 80 percent of output that could not be covered by UVRs. The aggregation procedure up to the level of total manufacturing was therefore carried out in a number of stages. First, the manufacturing sector was divided into sixteen branches, which roughly correspond to the International Standard Industry Classification (ISIC) of the United Nations. Within each branch we distinguished a maximum number of industries that produced the same products. Product matches were then made for as many products as possible within each industry. The average UVR for the industry was obtained by weighting the unit values by the corresponding quantity weights of one of the two countries:

$$(1a) \qquad UVR_{j(m)}^{XU(X)} = \frac{\sum_{i=1}^{s} P_{ij}^{X} * Q_{ij}^{X}}{\sum_{i=1}^{s} P_{ij}^{U} * Q_{ij}^{X}}$$

at quantity weights of country X, and

$$(1b) \qquad UVR_{j(m)}^{XU(U)} = \frac{\sum_{i=1}^{s} P_{ij}^{X} * Q_{ij}^{U}}{\sum_{i=1}^{s} P_{ij}^{U} * Q_{ij}^{U}}$$

at quantity weights of country U (that is, the United States). P_{ij} = price of item i in industry j, and Q_{ij} = quantity of item i in industry j. $i = 1 \ldots s$ is the sample of matched items in matched industry $j(m)$.

In some cases, the percentage of total sales covered within the industry was so low that the UVRs could not reasonably be assumed to

16. See also van Ark (forthcoming), who applied sensitivity tests for the effects of outlier UVRs and for systematic differences between UVRs for consumer goods and those for investment goods.

represent the whole industry. In Japan, at least 25 percent of total sales were matched in thirty-seven industries, whereas in Germany thirty-six industries met this criterion. These industries represented about 40 to 50 percent of total value added in manufacturing. For industries in which less than 25 percent of output was matched, or in which no matches were made at all, the quantity-weighted UVR of all matched items in a branch was assumed to be representative of the unknown UVR of the nonmatched industries in that branch.

The second stage of aggregation from industry to branch level was made by weighting the UVRs for gross output, UVR_{go}, as derived above, by the value added, VA, of each industry in country X or country U:

$$\text{(2a)} \qquad UVR_k^{XU(U)} = \frac{\sum_{j=1}^{r} [UVR_{j(go)}^{XU(U)} * VA_j^U]}{VA_k^U}$$

for the UVR of branch k at quantity weights of country U, and

$$\text{(2b)} \qquad UVR_k^{XU(X)} = \frac{VA_k^X}{\sum_{j=1}^{r} [VA_j^X \,/\, UVR_{j(go)}^{XU(X)}]}$$

for the UVR of branch k at country X's quantity weights. In the final stage, branch UVRs were weighted at branch value added to obtain a UVR for total manufacturing.

This aggregation by stages using either quantities (in the first stage from product to industry level) or value added (in the following stages) has the advantage that the original product UVRs are successively re-weighted according to their relative importance in the aggregate. As a result our aggregate UVRs are less sensitive to outlier UVRs.

The last three columns of table 1 show the UVRs at own country and U.S. weights and at their geometric (Fisher) average. The UVRs weighted at U.S. quantity weights are higher than the UVRs at local weights because of the "Gerschenkron" effect. In the remainder of this paper, we base our results on the geometric (Fisher) average of the UVRs, which stands out relatively well in terms of certain index number properties.[17] Furthermore, an important advantage of binary compari-

17. For example, in contrast to the Paasche and Laspeyres indexes, the Fisher index

sons is that the weights that are applied are the most "country characteristic."

It is clear from table 1 that, on the whole, the Fisher UVRs are substantially above the official exchange rates of 1.80 deutsche marks (DM) to the U.S. dollar and 144.6 yen to the U.S. dollar in 1987. This is in line with our expectations because of the relatively low exchange value of the U.S. dollar in that year.

The UVR for food manufacturing in Japan is most out of line with the average UVR. To a large extent that is attributable to the relatively highly priced agricultural inputs in this sector in Japan. Because we used our UVRs at value added level (see below), we considered it desirable to adjust the food products UVR_{go} for Japan for the relatively high prices of intermediate inputs in that sector. We used a price ratio of 825 yen to the U.S. dollar for agricultural inputs to adjust the output UVR for food products using input shares from the Japanese and U.S. input-output tables for 1987. This procedure reduced the UVR for food products, beverages, and tobacco from 320 yen to 243 yen to the dollar.[18]

We did not make separate unit value comparisons for intermediate inputs for the other branches. Even if quantity and value information for intermediate inputs were available (which is rarely the case), double deflation (that is, deflating output and intermediate inputs separately) easily leads to volatile and improbable results, particularly when intermediate inputs make up a large part of gross output or when the input-output structure differs greatly between countries. Our method in using output UVRs to convert value added by industry is referred to as the "adjusted

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satisfies the country reversal test (that is, changing the denominator and numerator does not alter the results) and the factor reversal test (that is, a Fisher price index times a Fisher quantity index gives a Fisher value index). In addition, Diewert (1981) stressed some economic theoretic properties of the Fisher index, one of them being that it is a "superlative" index number. Other studies on international comparisons, for example, the expenditure-based comparisons of the International Comparisons Project, have used multilateral weighting schemes to obtain PPPs that are transitive for more than two countries and that are independent of the base country chosen. For a comparison of three countries with fairly similar output structures in manufacturing, however, multilateralization changes the results only marginally. See Pilat and Prasada Rao (1991) for the use of multilateralization methods for our ICOP comparisons.

18. See Prasada Rao (1993) for the latest measures of agricultural PPPs based on prices paid to farmers.

single indicator'' method and, in general, can be accepted as sufficiently robust for the purpose.[19]

Benchmark Comparisons of Value Added and Labor Productivity

A major feature of our approach is that the comparisons of real output and productivity are derived simultaneously with the UVRs, because the information is taken largely from the same source or from directly related sources.

In this study we focus on comparisons of value added derived from production censuses. The ''census concept'' of value added is somewhat broader than the definition commonly used in the national accounts. The census concept is defined as gross value of output minus the cost of raw materials, packaging, energy inputs, and contract work. Under this definition, value added still includes the value of purchased industrial and nonindustrial services (including repair and maintenance, advertising, and accountancy). In fact, these services are not even reported in the U.S. and Japanese production censuses, but information from input-output tables shows that the share of services in total intermediate inputs in manufacturing does not differ much between these countries.[20]

Some authors have argued that for sectoral comparisons it would be desirable to measure gross output instead of value added, because, for an analysis of competitiveness or technological supremacy, one should take into account not only the relative level of labor and capital (which together constitute value added) but also the relative level of interme-

19. See Paige and Bombach (1959); Szirmai and Pilat (1990) show a test of double-deflated versus single-deflated output for their Japan-U.S. comparison for 1975.

20. In 1987 purchased services accounted for 25.6 percent of intermediate inputs in U.S. manufacturing (U.S. Dept. of Commerce, *Survey of Current Business*, April 1992). The corresponding percentage was 23.8 for Japan (MITI, *1987 Input-Output Tables*, Tokyo) and 25.9 for Germany (Statistische Bundesamt, *Input-Output Tabellen, 1985 bis 1988*, Wiesbaden). It should be emphasized that our estimates for Germany are based on census information for legal units (enterprises) and not on an activity basis, as they are in the input-output tables. According to the German census, the share of service inputs in total intermediate inputs is 18.6 percent. Germany is generally known for its relatively small share of outsourcing of service activities. See, for example, Ockel and Schreyer (1988).

diate inputs.[21] Measuring the effect of intermediate inputs on the comparative productivity performance separately requires a detailed account of intermediate inputs (including their prices—which are not the same as the output prices of corresponding products—and quantities). Such detail is difficult to obtain in practice and is very sensitive to the measurement procedure explained above. Furthermore, gross output involves a good deal of double counting of output that is used as an intermediate input elsewhere, and that double counting complicates the aggregation of the industry and sectoral results to total GDP. Hence, with our focus on value added rather than gross output, we do not treat differences in efficiency related to the use of intermediate inputs as a separate explanatory factor in our analysis.

Our employment figures refer to the total number of employees on the payroll of the manufacturing units. This also includes employees in so-called auxiliary units, which are establishments at a different location from the producing units, but which perform a direct supporting function, such as administration, research and development, or marketing. These units were not included in Japan's census, but we added them, using information from the *1986 Establishment Census of Japan*. Apparently, the number of employees in auxiliary units was substantially higher in Japan than in the United States, accounting for about 14.5 percent of total manufacturing employment in Japan, compared with 6.5 percent in the United States.[22]

Total labor input was also adjusted for differences in the number of hours each employee worked. In 1987 manufacturing employees worked an average of 1,909 hours in the United States, 1,630 in Germany, and 2,161 in Japan. These estimates refer to ''actual hours,'' which are paid hours adjusted downward to exclude hours not worked because of holidays, vacation, sickness, and the like. The longer hours

21. See, for example, Jorgenson, Gollop, and Fraumeni (1987). Ideally, such comparisons should be made within the framework of an input-output table that shows all transfers of output from one sector to another and that simultaneously derives expenditure, gross output, and value added. To make this approach work, however, one needs to apply representative prices and quantities to all cells in the matrix. As we showed above, separate UVRs for intermediate inputs are very hard to obtain in practice. Moreover, in using input-output tables, one loses one of the fundamental advantages of census material—the direct link between output and labor input information.

22. We had no separate figures on auxiliary units in Germany, but they were included in the total.

Table 2. Comparison of Value Added, Value Added per Employee, and Value Added per Hour Worked by Major Manufacturing Branch, 1987
U.S. = 100

Branch	*Value added*	*Value added per employee*	*Value added per hour worked*
Germany/U.S.[a]			
Food, beverages, tobacco	20.2	66.8	69.2
Textiles, apparel, leather	17.9	73.2	87.2
Chemicals, allied products	28.9	58.9	70.6
Basic, fabricated metals	33.2	69.8	86.0
Machinery, equipment	40.7	72.4	86.0
Other manufacturing[b]	15.8	69.9	79.1
Total manufacturing	28.2	70.2	82.2
Japan/U.S.			
Food, beverages, tobacco	23.4	28.4	25.2
With double deflation for food	30.9	37.4	33.3
Textiles, apparel, leather	50.5	64.4	56.4
Chemicals, allied products	46.1	80.1	75.8
Basic, fabricated metals	63.5	91.6	82.0
Machinery, equipment	81.8	106.7	93.2
Other manufacturing[b]	29.5	57.7	50.0
Total manufacturing	49.7	74.2	65.6
With double deflation for food	51.2	76.4	67.5

Source: See table 1 and tables A-3 and A-4. All estimates are based on the geometric average of the UVRs at own country weights and at U.S. weights from table 1.
a. The Germany-U.S. comparison excludes units with fewer than twenty employees.
b. The Germany-U.S. comparison for other manufacturing excludes publishing.

in Japan reflect both more paid hours and shorter holidays. Paid hours of employees in Germany and the United States are some 300 hours a year less than in Japan. Relatively long holidays are the main reason for shorter working time in Germany compared with the United States.

The first column in table 2 shows comparisons of value added for Germany and Japan with that in the United States for 1987. It appears that manufacturing value added was about half that of the United States in Japan, and just over a quarter of the U.S. level in Germany. In both Germany and Japan the real output in U.S. dollars in basic metals and metal products and in machinery and transport equipment is relatively large compared with the other branches.

Table 3. Annual Compound Growth Rates of Real Value Added and Real Value Added per Hour by Major Manufacturing Branch, 1950–90

	Real value added				*Real value added/hour*			
Branch	*1950–1965*[a]	*1965–1973*	*1973–1979*	*1979–1990*	*1950–1965*[a]	*1965–1973*	*1973–1979*	*1979–1990*
Germany								
Food, beverages, tobacco	7.42	1.97	1.74	−0.65	5.74	2.80	3.51	0.79
Textiles, apparel, leather	7.45	−0.48	−1.03	−1.41	7.29	3.24	4.80	2.89
Chemicals, allied products	12.09	9.29	2.24	0.79	8.20	8.03	3.98	0.33
Basic, fabricated metals	7.91	3.26	0.90	0.64	5.24	4.60	4.38	1.89
Machinery, equipment	12.01	5.38	2.67	2.37	6.42	4.52	4.67	2.25
Other manufacturing	8.20	4.37	0.57	0.02	6.29	5.22	3.54	1.36
Total manufacturing	9.38	4.60	1.70	1.02	6.53	5.11	4.44	1.80
Japan								
Food, beverages, tobacco	6.17	9.03	2.06	0.71	3.11	10.06	2.23	−0.07
Textiles, apparel, leather	10.77	7.63	1.79	0.78	8.05	7.36	4.34	1.42
Chemicals, allied products	20.12	13.89	3.80	5.36	13.88	12.04	5.69	3.99
Basic, fabricated metals	15.29	18.30	1.65	2.90	7.95	14.85	4.82	2.20
Machinery, equipment	23.25	16.79	6.77	10.93	14.10	12.80	9.07	7.96
Other manufacturing	14.89	11.22	1.94	3.82	10.50	9.72	3.66	4.47
Total manufacturing	13.05	13.03	3.35	5.88	7.75	11.04	5.42	4.88
United States								
Food, beverages, tobacco	2.83	3.56	1.86	0.44	3.17	4.32	2.13	0.58
Textiles, apparel, leather	2.78	2.91	1.46	0.44	3.27	2.77	3.78	2.65
Chemicals, allied products	5.53	5.78	2.90	3.41	3.37	3.51	1.28	3.32
Basic, fabricated metals	2.57	2.62	−0.69	−1.48	1.45	1.67	−0.59	1.05
Machinery, equipment	5.48	3.86	2.65	3.82	2.46	2.52	1.12	4.47
Other manufacturing	3.62	3.87	1.80	1.88	2.77	2.68	0.96	1.46
Total manufacturing	3.96	3.78	1.79	2.18	2.76	2.81	1.27	2.82

Source: See sources in data appendix.

a. 1955–65 for Japan; the 1950–65 growth rate for total manufacturing is 13.9 percent for GDP and 8.5 percent for real value added per hour.

The second and third columns of table 2 show the corresponding ratios of labor productivity for the two comparisons on the basis of either employees or hours worked. Productivity performance relative to the United States appears to vary considerably between the major branches. Value added per hour worked in German manufacturing ranges from 69 to 87 percent of the U.S. level, but in Japan it ranges from 25 to 93 percent. Even after correcting for the high prices of agricultural inputs, productivity in food products, beverages, and tobacco remains the major outlier at only 33 percent of the U.S. productivity level. Japan, however, was close to the U.S. productivity level in basic metals and metal products and in machinery and equipment.

Trends in Comparative Labor Productivity

The 1987 benchmark results for labor productivity were extrapolated on the basis of national time series for real output and labor input. Table 3 shows the annual compound growth rates of value added and labor productivity from 1950 to 1990. It appears that throughout the postwar period, Japan showed the fastest growth of output and productivity for manufacturing as a whole, although it experienced a serious setback during the second half of the 1970s, when productivity growth fell from 11.0 percent a year in the earlier period to only 5.4 percent. Japanese growth was especially rapid in the investment goods sector, and the slowdown of productivity growth during the 1970s was also less in that branch than in the others (from 12.8 percent in 1965–73 to 9.1 percent in 1973–79).

In Germany growth slowed throughout the period, but the setback was particularly large during the 1980s, when the average productivity growth rate for total manufacturing was only 1.8 percent a year, and even lower in food products (0.8 percent) and chemicals (0.3 percent).

U.S. productivity growth in manufacturing was slower than in the other two countries, until the 1980s, when the growth rate recovered, especially in chemicals and machinery and equipment.[23] U.S. productivity growth in these latter branches was much faster than in Germany

23. Especially between 1979 and 1982, the United States experienced a strong decline in manufacturing output. The compound productivity growth rate from 1973 to 1982 was slightly negative at −0.09 percent a year.

during the last decade, a fact which underlies the diverging trend in the comparative productivity performance between the two countries.

Before discussing the comparative productivity levels, we need to look briefly at the consistency of the national accounts series of manufacturing real output in the three countries. Gordon and Baily attributed part of the estimated gain of U.S. manufacturing output compared with Germany and Japan (and also with France and the United Kingdom) to the use of 1982 fixed weights in the U.S. national accounts in combination with a more rapidly decreasing price trend in computers.[24] Elsewhere we experimented with the U.S. GDP series, where instead of fixed weights, we used shifting base year weights for subperiods of five years.[25] The latter is common practice in the national accounts of Germany and Japan. We found that compared with the German and Japanese series, the U.S. growth rates were particularly affected by the fixed weight system from 1987 onward. For the latter period, we therefore linked the recently published 1987 fixed weight series to the 1982 fixed weight series for the previous period.

The use of a hedonic price index for computers led to a relatively rapid increase of U.S. real output in machinery and equipment, especially between 1982 and 1985. The U.S. deflator for this branch, which could be implicitly derived from the national accounts, showed a decrease of one-third in only three years.[26] Hedonic price indexes consider products as a bundle of quality characteristics, each representing a price premium that is derived by regression analysis. They differ from conventional price indexes, which are based on "matched models," a procedure that is difficult to implement in the rapidly changing computer industry. Although hedonic price indexes are not explicitly used for the deflation of computer output in the national accounts of Germany and Japan, the deflator for office machinery in Germany and for electrical machinery (which includes computers) in Japan both show a significant price drop. Although it would be desirable if other countries would follow the U.S. practice of using the hedonic pricing technique

24. See Gordon and Baily (1991). They also discuss the puzzle of the limited effect that the rise in computer output appears to have had on the growth of U.S. nonmanufacturing output. See also Baily and Gordon (1988); and Denison (1989).

25. Van Ark (forthcoming).

26. After 1985 the deflator for machinery and equipment declined less rapidly, in particular when using 1987 weights from 1987 onward. See Young (1989); and Sinclair and Catron (1990).

Table 4. Comparison of Value Added per Hour Worked in Major Manufacturing Branches, 1950–90

U.S. = 100

Branch	*1950*[a]	*1965*	*1973*	*1979*	*1990*
Germany/U.S.					
Food, beverages, tobacco	53.1	76.9	68.4	74.1	75.8
Textiles, apparel, leather	44.0	78.1	81.0	85.9	88.2
Chemicals, allied products	32.4	64.3	90.5	106.0	76.7
Basic, fabricated metals	30.9	53.6	67.2	90.1	98.8
Machinery, equipment	43.7	77.1	90.0	110.7	87.6
Other manufacturing	34.2	56.6	68.8	80.1	79.3
Total manufacturing	38.9	66.7	79.7	95.8	85.9
Japan/U.S.					
Food, beverages, tobacco	26.7	25.8	39.5	39.8	37.0
Textiles, apparel, leather	24.7	37.5	53.2	54.9	48.0
Chemicals, allied products	13.0	32.1	60.4	78.0	83.8
Basic, fabricated metals	12.5	23.1	61.4	84.3	95.6
Machinery, equipment	8.0	23.5	50.6	79.6	114.4
Other manufacturing	9.7	20.0	34.0	39.8	54.9
Total manufacturing	16.6	26.6	49.2	62.6	77.9

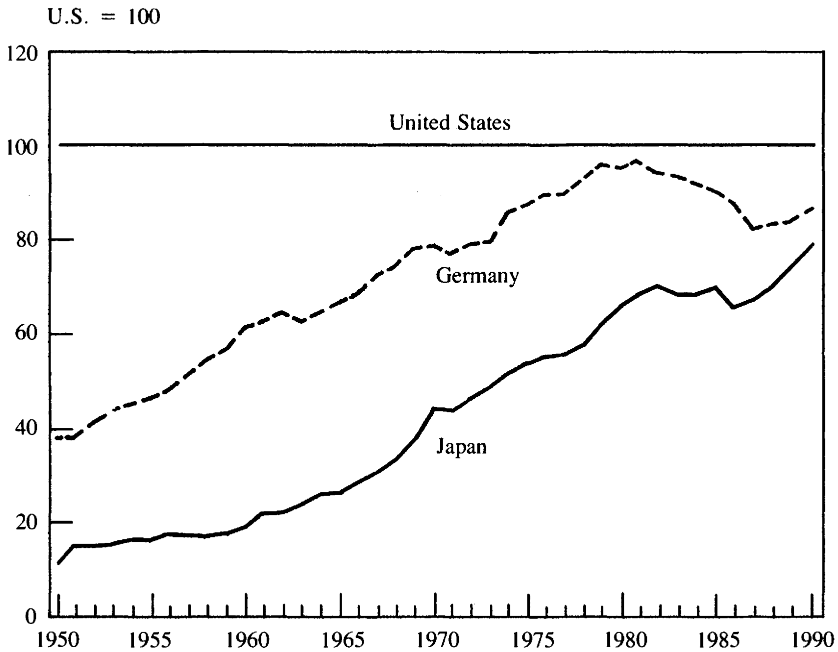
Source: See tables 2 and 3.
a. 1955 for Japan.

for products whose quality characteristics change rapidly, we do not expect that our main facts on the changes in comparative productivity performance over time, as presented below, would change significantly.

The time series for real output and labor input in total manufacturing and for the major branches from 1950 to 1990 were linked to the benchmark estimates of relative productivity levels for 1987 to obtain trends of comparative productivity levels. Table 4 and figure 1 show that until the early 1980s both Japan and Germany converged rapidly on the U.S. manufacturing labor productivity level. By the beginning of the 1980s, Germany had almost the same productivity level as the United States. Since then Germany has begun to fall behind, although a slight recovery took place between 1987 and 1990. Although the Japanese comparative productivity level also stagnated during the first half of the 1980s, it clearly returned to the catch-up track thereafter. Since 1985 the productivity gap between Germany and Japan has decreased very rapidly.

Table 4 and figure 2 show that the dynamics of the changes in

Figure 1. Comparison of Value Added per Hour Worked in Manufacturing, 1950–90



Source: See table 5.

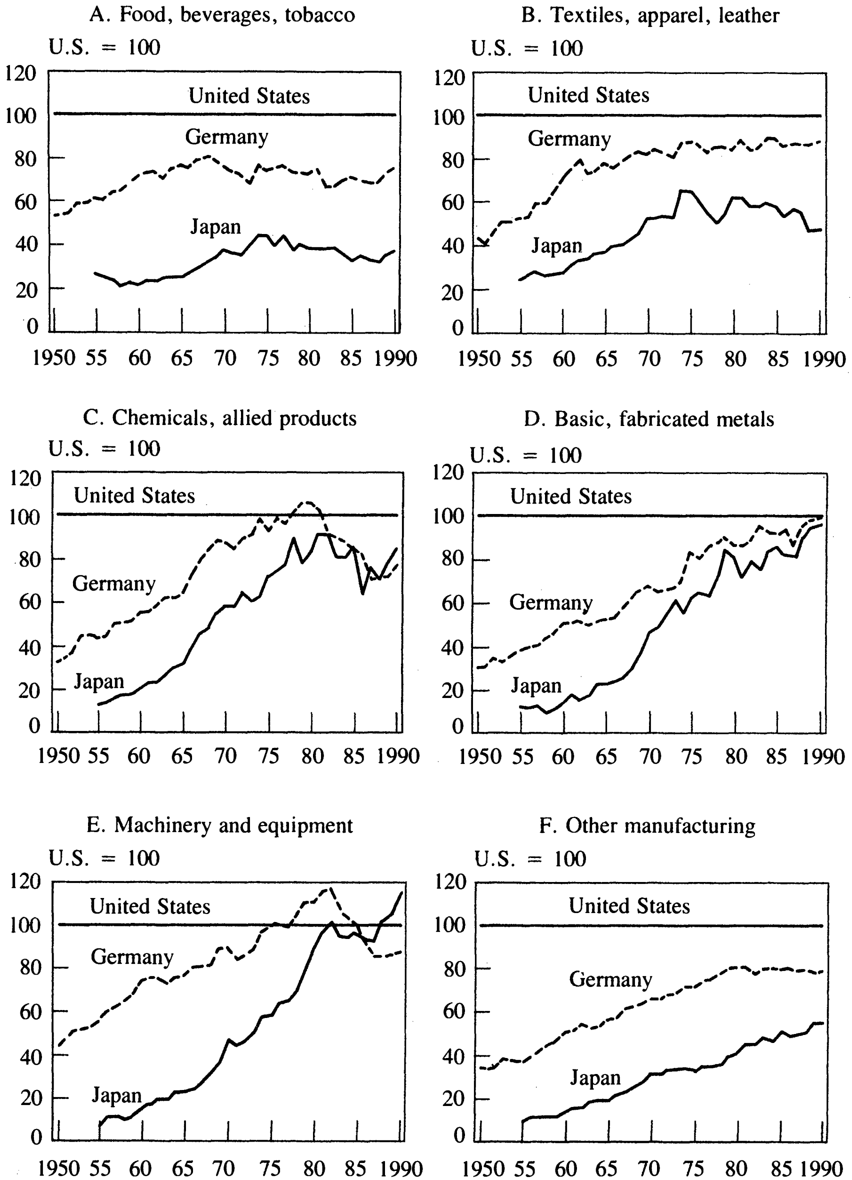
comparative productivity levels were different across branches. In the early postwar decades, the catch-up of Germany and Japan was strong in most branches, in particular in chemicals, basic metals and metal products, and machinery and equipment. By 1979 the productivity gaps in these branches had substantially narrowed and in some cases had almost disappeared. In machinery and transport equipment Japan is now clearly leading the United States.

The United States has been better able to maintain its leadership position in the lighter industries, where it continued to benefit from the mass production in these branches. German and Japanese productivity in branches such as food products and wearing apparel was stifled by relatively small plant sizes and lack of economies of scale.[27]

Since 1982 Germany has lost much of the relative improvement in productivity it had achieved during the 1970s. In chemicals Germany's

27. See also the discussion on plant size in the next section.

Figure 2. Comparison of Value Added per Hour Worked by Major Branch, 1950–90



Source: See table 4.

Table 5. Comparison of Value Added per Hour in Manufacturing and the Total Economy, 1950–90

U.S. = 100

Sector	*1950*	*1960*	*1973*	*1979*	*1990*
Germany					
Total economy	27.6	42.0	59.0	69.6	75.2
Manufacturing	38.9	61.6	79.7	95.8	85.9
Japan					
Total economy	12.6	17.2	39.8	45.0	55.0
Manufacturing	11.8	19.5	49.2	62.6	77.9

Source: See table 4 for manufacturing estimates. For total economy, GDP (in national currencies) and employment 1960 to 1990 from OECD. *National Accounts Main Aggregates*, various issues; and OECD. *Labor Force Statistics*. Total economy for 1950 and hours for the whole period from Maddison (1982, 1990). Hours for 1990 refer to 1985. In accordance with our manufacturing estimates, the total economy figures are converted to U.S. dollars with Fisher PPPs for 1985 (provided by EUROSTAT).

comparative productivity performance in 1990 was much worse than in the early 1970s, and the productivity gap also widened in machinery and transport equipment. In 1990 Germany had productivity levels close to those of the United States only in textiles and in basic metals and metal products.

Summarizing, we conclude that although the United States is clearly still the productivity leader, its position is more secure in light industries than in heavy and investment industries. For manufacturing as a whole, we can speak of a "shared leadership" between Japan and the United States. It is unlikely that Japan will be able to converge on the U.S. productivity level in all branches of manufacturing in the near future. Germany does not appear to be a participant in this "leadership contest." Since the beginning of the 1980s, Germany's comparative productivity level by branch has either remained stable or diverged from the U.S. level. Furthermore, by the end of the 1980s, Germany's productivity performance was better than Japan's only in light industries.

One specific point of interest is how the comparative productivity results in this paper compare with studies for the economy as a whole. The catch-up of OECD countries, including Germany and Japan, to U.S. per capita income and productivity levels has been extensively documented by various scholars,[28] but so far the role of the individual sectors has received less attention. Table 5 compares the relative productivity ratio for the economy as a whole with that for manufacturing.

28. For instance, Abramovitz (1986); Baumol (1986); and Maddison (1982, 1991).

It is clear that throughout the postwar period the catch-up process for manufacturing reflected the pattern for the economy as a whole. Only the relative productivity performance of German manufacturing during the 1980s did not conform to this pattern: whereas the productivity gap between Germany and the United States for the economy as a whole was smaller in 1990 than in 1979, the manufacturing productivity gap widened during this period.[29]

Throughout the period both Germany and Japan showed a better productivity performance relative to the United States in manufacturing than for the economy as a whole. The productivity gap in manufacturing also narrowed more rapidly than for the total economy in both countries. Manufacturing therefore was one of the driving forces behind the catch-up and convergence process in the first three decades after World War II. Except for a few years of stagnation at the beginning of the 1980s, the manufacturing sector in Japan continued to contribute to the catch-up process for the economy as a whole.[30] However, this process came to a virtual standstill in German manufacturing. Which forces account for the ongoing process of catch-up in value added per hour worked in the nonmanufacturing part of the German economy is an intriguing issue that goes beyond the scope of this paper. In the next section we address in more detail the factors that account for the productivity gaps in manufacturing.

The Causes of the Productivity Gaps

Estimates of labor productivity can be referred to as "single factor productivity" or "partial productivity." They measure the output per unit of labor input, which after an adjustment for differences in hours worked and labor force participation rates, can be converted into comparative measures of per capita income. Sectoral estimates of labor productivity also make it possible to search for the factors that account for productivity gaps.

29. Van Ark (forthcoming) records a similar pattern in three other West European countries—France, the Netherlands, and the United Kingdom—as in Germany, but in none of these other countries was the widening of the manufacturing productivity gap as big as in Germany.

30. See Pilat (1993) for more details on the contribution of sectoral growth to overall performance of the Japanese economy.

In the "level accounting" approach that we develop in this section, the contribution to the productivity gap of differences in capital intensity and labor quality is analyzed in detail. We also look at the effect of differences in the branch composition of manufacturing employment and the size of manufacturing plants, but we do not integrate these with the first two factors because substantial interaction effects between these factors may lead to an overexplanation of the productivity gap. Last, we look at some areas where further analysis is required to account for the productivity gap.

The Capital Intensity Effect

The greater use of capital goods in the manufacturing production process is probably one of the most important reasons why the United States achieved productivity leadership in manufacturing as far back as the mid-nineteenth century.[31] Germany and Japan also invested heavily in capital, especially during the postwar period. Between 1950 and 1973 the average growth rate of manufacturing investment was 7.5 percent in Germany and 15.0 percent in Japan, against only 4.2 percent in the United States. These differences in investment growth have led to a convergence of capital intensity, which underlies the narrowing of the labor productivity gaps observed above.

The stock of structures and equipment in manufacturing is calculated on the basis of the perpetual inventory method by cumulating annual investments and by deducting a share of the existing capital stock to account for the investment made in an earlier year that has reached the end of its lifetime. For this study we "standardized" the assumptions on asset lives and scrapping patterns for each country, because the comparability of the official estimates for the various countries is very weak. We then converted these capital stock estimates into U.S. dollars, making use of the expenditure PPPs for capital formation in machinery and equipment and in structures.[32]

Table 6 shows comparative estimates of the stock of structures and equipment per manufacturing employee in Germany and Japan as a percentage of the U.S. estimate. The estimates for total manufacturing

31. Broadberry (1992).

32. See the data appendix for a detailed description of our estimates of the manufacturing capital stock.

Table 6. Comparison of Gross Stock of Structures and Equipment per Employee by Major Branch in Manufacturing, 1950–90

U.S. = 100

Branch	*1950*[a]	*1960*	*1973*	*1979*	*1990*
Germany/U.S.					
Food, beverages, tobacco	58.1	75.5	147.1	146.0	132.6
Textiles, apparel, leather	51.5	76.7	159.4	170.3	189.3
Chemicals, allied products	64.3	45.8	70.1	72.9	59.1
Basic, fabricated metals	57.7	50.2	92.5	98.2	71.3
Machinery, equipment	64.4	54.3	75.0	86.3	73.3
Other manufacturing	37.1	45.8	89.4	99.4	102.4
Total manufacturing	53.1	51.3	87.4	94.2	82.4
Equipment only	47.8	46.2	92.2	94.8	81.5
Japan/U.S.					
Food, beverages, tobacco	13.1	7.5	36.9	48.3	60.2
Textiles, apparel, leather	33.8	22.9	76.2	82.9	103.9
Chemicals, allied products	16.5	14.2	58.0	79.4	86.8
Basic, fabricated metals	46.9	30.9	82.2	126.0	117.5
Machinery, equipment	22.2	15.9	52.8	77.5	80.6
Other manufacturing	10.3	13.8	40.2	57.7	93.4
Total manufacturing	20.1	16.2	54.1	75.4	86.7
Equipment only	28.0	20.2	70.2	93.1	106.4

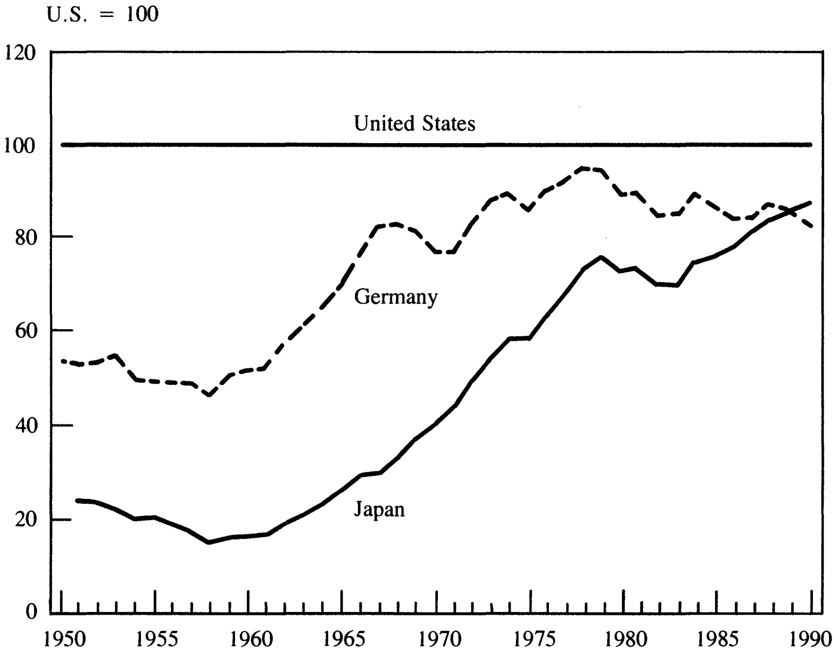
Sources and method: See data appendix. Capital stock estimates are based on the perpetual inventory method, using standardized assumptions on asset lives and retirement patterns and ICP PPP converters for equipment and structures.

a. 1955 for Japan.

are also reproduced in figure 3. Although capital intensity grew slightly faster in the United States than in Germany and Japan during the 1950s, the latter countries quickly caught up to the U.S. level during the 1960s and 1970s. During the 1980s the catch-up slowed in Germany but continued in Japan. Table 6 also separates out equipment from the total manufacturing capital stock per employee, and it shows an even more pronounced catch-up trend for capital intensity, particularly for Japan. In the late 1980s Japanese capital intensity in machinery and equipment surged ahead of that in the United States. Recently, De Long and Summers emphasized the importance for growth of these investments.[33] Machinery and equipment now make up more than 60 percent of the total capital stock in manufacturing in Germany and the United States; during the 1950s they accounted for only 45 to 50 percent. In Japan

33. De Long and Summers (1991).

Figure 3. Comparison of Capital Stock per Employee in Manufacturing, 1950–90



Source: See table 6.

machinery and equipment accounted for about three-quarters of the total capital stock in manufacturing throughout the postwar period.[34]

To analyze the impact of the different levels of capital intensity for major branches and across the three countries, we calculated relative levels of value added per joint unit of labor input and capital. For this purpose we adopted a Cobb-Douglas production function with constant returns to scale. A fixed factor share for labor was obtained from national accounts sources for 1987.[35] The Cobb-Douglas function can be

34. For a more detailed assessment, see van Ark (forthcoming).

35. The factor shares for labor were obtained from each country's national accounts (see source description in the data appendix) and were defined as the ratio of labor costs to the gross domestic product in manufacturing minus indirect taxes plus subsidies. For the United States, we had to use the unpublished tabulation of the Department of Commerce to make the adjustment from market prices to factor cost. Apart from wages and salaries, labor costs also include supplementary payments for labor input by employers, but not the income of self-employed persons and unpaid family workers. In the national accounts the latter is included with the operating surplus. As a result the

reformulated by subtracting the logarithmic index of the relative capital-labor ratio of countries X and U (K^X/L^X over K^U/L^U) from that of the corresponding ratio of labor productivity (Y^X/L^X over Y^U/L^U):

$$(3) \qquad \ln \frac{A^X}{A^U} = \ln \frac{Y^X/L^X}{Y^U/L^U} - (1 - \alpha) \ln \frac{K^X/L^X}{K^U/L^U},$$

with α representing the unweighted average of the share of labor compensation in gross domestic product at factor cost in country X and country U in 1987.

Benchmark comparisons of joint factor productivity were made for 1987 and extrapolated over the postwar period on the basis of national time series. The relative levels of joint factor productivity by major branch are presented in table 7 and are also reproduced for total manufacturing in figure 4. At first sight the comparative trends in joint factor productivity look similar to those of relative labor productivity shown in figure 1, and, indeed, the relation between the two measures is strong. If figures 1 and 4 are compared in more detail, however, it appears that labor productivity converged more rapidly on the U.S. level than did joint factor productivity. In 1950 the labor productivity gap was larger than the joint factor productivity gap for both Germany and Japan because of the higher capital intensity in the United States. The catch-up in labor productivity levels until the early 1980s is partly associated with a relative increase in capital intensity, as shown above, but other factors have figured in the catch-up process as well.

By the end of the 1980s, differences in capital intensity explained a negligible part of the difference in labor productivity levels between Germany and the United States but slightly more for the Japan-U.S. comparison. Japan's joint factor productivity relative to the United

contribution of labor input to output is slightly underestimated, although the share of income for self-employed and unpaid family workers in manufacturing labor compensation in advanced countries is small. We also estimated joint factor productivity on the basis of annual weights, which increased the joint factor productivity levels of Germany and Japan only slightly relative to the United States, because of the relatively lower labor shares of these countries in the 1950s and 1960s. In their recent work on growth theory Lucas (1988) and Romer (1990) have argued in favor of increasing returns to scale because of higher returns to human or physical capital than their factor shares suggest. The empirical support for substantially increasing returns to scale is not very strong. At best there are slightly increasing returns to scale but diminishing returns on each of the individual production factors. See Crafts (1992) for a review of the empirical evidence based on "new growth" models.

Table 7. Comparison of Value Added per Joint Unit of Labor and Capital by Major Branch in Manufacturing, 1950–90

U.S. = 100

Branch	*1950*[a]	*1960*	*1973*	*1979*	*1990*
Germany/U.S.					
Food, beverages, tobacco	70.7	83.9	59.1	63.2	64.7
Textiles, apparel, leather	53.7	77.0	70.5	73.5	72.2
Chemicals, allied products	39.6	73.1	99.5	113.1	86.1
Basic, fabricated metals	36.3	61.0	67.4	88.0	101.2
Machinery, equipment	49.8	85.6	94.5	111.9	89.7
Other manufacturing	49.1	67.1	71.2	79.2	76.2
Total manufacturing	47.9	75.0	81.5	95.1	86.2
Japan/U.S.					
Food, beverages, tobacco	70.4	74.9	64.1	57.6	47.2
Textiles, apparel, leather	34.2	43.9	59.1	60.0	49.4
Chemicals, allied products	35.9	62.8	82.9	90.2	92.8
Basic, fabricated metals	17.4	24.4	68.7	81.6	94.1
Machinery, equipment	13.3	28.8	63.5	89.4	126.6
Other manufacturing	23.1	30.8	49.3	51.0	59.1
Total manufacturing	30.9	40.1	63.7	72.4	85.1

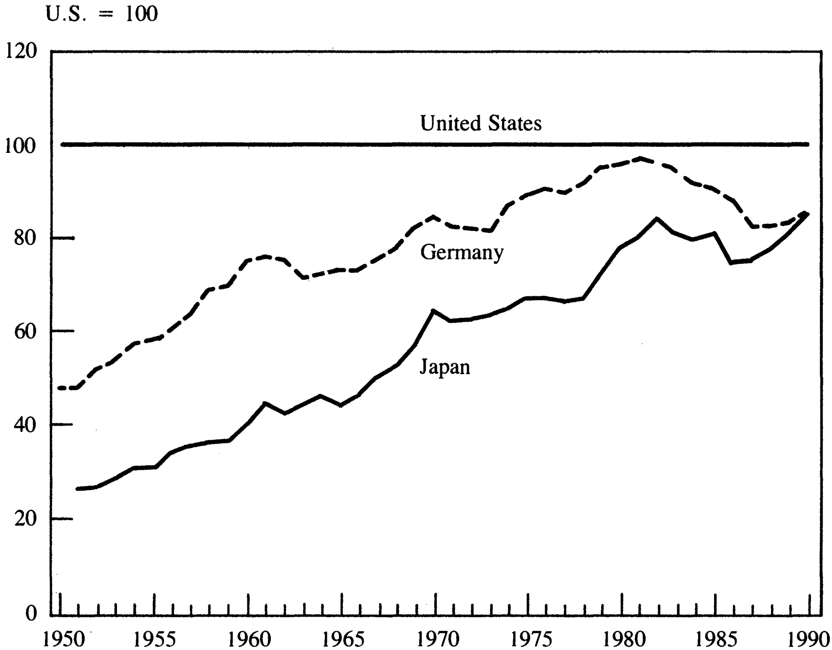
Source: See tables 4 and 6 and with adjustment for capital intensity from capital stock per employee to capital stock per hour. Joint factor productivity is based on a Cobb-Douglas function with constant returns to scale, using average unweighted factor shares for labor in 1987 for each pair of countries as the coefficients. For total manufacturing the factor labor shares in 1987 were 73.4 percent for Germany, 57.2 percent for Japan, and 73.8 percent for the United States (see also footnote 35).

a. 1955 for Japan.

States is now close to that of Germany. It appears that as the labor productivity gap widened between Germany and the United States, joint factor productivity also deteriorated in relative terms. Along with the slowdown in growth of manufacturing output in Germany during the 1980s, growth in the capital stock also fell, but it appears that not enough labor was laid off to keep joint factor productivity at the level of the late 1970s.

In Germany the relative positions of the major branches do not change significantly after adjusting for differences in capital intensity. The one exception is textiles, where joint factor productivity performance is much lower than labor productivity performance, apparently because capital intensity levels are very high. In Japan the good performance of the machinery and equipment branch is even more pronounced after adjusting for capital intensity.

Figure 4. Comparison of Value Added per Joint Unit of Labor and Capital Input in Manufacturing, 1950–90



Source: See table 7.

The Quality of Labor Input

So far the accounting for the role of labor and capital in explaining the productivity gaps in manufacturing has been entirely focused on the quantities of these inputs. Differences in the quality of the factor inputs should also be taken in account. We therefore need to look in some more detail at the level of education of the manufacturing labor force in the three countries.

Most studies of the role of education in economic growth look at the average number of years of schooling of the population. Such measures, however, do not provide information on the actual distribution of skills across sectors. Table 8 shows the distribution of skills among the labor force for 1987 based on the highest level of formal schooling received, which is obtained from the national labor force and population surveys. Most manufacturing employees do not have more than a high school education, although this is less true for "skill-intensive" branches such as chemicals and machinery and equipment. Nevertheless, 34 percent of manufacturing employees in the United States hold postsecondary degrees, compared with 28 percent in Germany and only 17 percent in Japan.

We developed an average labor quality index by weighting the shares for each of the education levels at their relative wages.[36] More precisely, we took the arithmetic average for each country and the United States of the wage differentials in total manufacturing. Following Denison[37] this differential was reduced by 40 percent to exclude the effect of other factors on wage differences, such as ability or social background. Under this procedure, the average labor quality index for total manufacturing was 96.5 percent of the U.S. level for Germany and 97.4 percent for Japan.

Estimates of general education levels tend to understate the contribution of education to manufacturing productivity performance. First, these estimates do not take into account on-the-job training. Second, they do not adjust for the vocational content of the schooling. Studies by the National Institute of Economic and Social Research show that education received at technical colleges or through an apprenticeship system and the possession of vocational certificates are more important for explaining productivity differentials in manufacturing than years of general schooling.[38]

Adjustments for vocational qualifications appear to be especially important for Germany, where a large proportion of the labor force obtained certificates through vocational schools and apprenticeship systems. Table 9 shows the distribution of the manufacturing labor force according to levels of vocational qualifications in Germany and the United States. For the United States the adjustment to a distribution based on vocational skills is fairly crude, because the U.S. statistics do not clearly distinguish between vocational and general qualifications at the high school level.[39] It appears from table 9 that intermediate voca-

36. Wages were derived from the same sources as the education levels, although for Germany and the United States they were available only for total manufacturing.

37. Denison (1967).

38. See, for example, Prais (1981); and results from comparisons of "matched plants" by Daly, Hitchens, and Wagner (1985) covering Germany and the United Kingdom.

39. See the description of our sources in the data appendix. In the United States,

Table 8. Distribution of Employees according to Highest Level of General Education Completed by Major Branch in Manufacturing, 1987
Percentage

Branch	*Elementary or junior high school*	*Senior high school*	*Junior college*	*Senior college, university*
Germany				
Food, beverages, tobacco	80.6		14.8	4.6
Textiles, apparel, leather	80.1		14.9	4.9
Chemicals, allied products	60.1		22.8	17.0
Basic, fabricated metals	78.3		15.2	6.5
Machinery, equipment	67.5		19.5	12.9
Other manufacturing	76.2		17.6	6.2
Total manufacturing	72.2		18.1	9.7
Japan				
Food, beverages, tobacco	32.4	53.6	2.8	11.2
Textiles, apparel, leather	44.9	48.2	1.4	5.4
Chemicals, allied products	21.9	51.8	4.4	21.8
Basic, fabricated metals	36.3	49.5	3.2	11.0
Machinery, equipment	26.4	53.3	5.0	15.3
Other manufacturing	32.9	49.2	4.3	13.7
Total manufacturing	31.2	51.3	4.0	13.5
United States				
Food, beverages, tobacco	26.9	50.3	12.9	9.8
Textiles, apparel, leather	39.0	45.7	7.8	7.5
Chemicals, allied products	14.1	43.7	16.8	25.4
Basic, fabricated metals	23.2	48.4	16.8	16.8
Machinery, equipment	15.4	42.3	19.8	22.4
Other manufacturing	20.4	45.7	16.6	17.4
Total manufacturing	20.8	45.0	16.5	17.7

Sources and notes: See data appendix.

tional qualifications (in particular at craft level) are of much greater importance in German manufacturing than in the United States, which partly compensates for Germany's lower proportion of employees with postsecondary levels of general education. As a result the German labor

the provision of separate schools for vocational training below college level has traditionally been limited. Neither have apprenticeship systems been of great importance. Most general high schools, however, offer technical subjects that students can choose to integrate into their program.

Table 9. Distribution of Employees According to Highest Level of Vocational Education Levels by Major Branch in Manufacturing, 1987
Percentage

Branch	*No vocational qualifications*	*Intermediate*		*Higher vocational qualifications*
		Lower	*Upper*	
Germany				
Food, beverages, tobacco	33.5	55.0	9.9	1.6
Textiles, apparel, leather	39.4	53.2	5.9	1.6
Chemicals, allied products	25.2	56.1	7.9	10.8
Basic, fabricated metals	32.6	57.5	6.7	3.2
Machinery, equipment	25.5	57.0	8.9	8.6
Other manufacturing	30.9	57.7	8.5	2.8
Total manufacturing	29.3	56.7	8.4	5.7
United States				
Food, beverages, tobacco	75.4	14.8		9.8
Textiles, apparel, leather	80.3	12.2		7.5
Chemicals, allied products	59.5	15.1		25.4
Basic, fabricated metals	72.1	16.3		11.6
Machinery, equipment	61.1	16.5		22.4
Other manufacturing	67.0	15.6		17.4
Total manufacturing	66.8	15.5		17.7

Sources: See data appendix.

quality index for total manufacturing rises from 96.5 percent of the U.S. level on the basis of general education to 98.5 percent applying a distribution of vocational qualifications.

Table 10 shows that the effect of adjusting the joint factor productivity gap in total manufacturing for differences in labor quality is fairly small for 1987, especially after the Germany-U.S. comparison is adjusted for vocational qualifications. The effect appears to be slightly more important in chemicals and machinery and equipment, where the United States takes advantage of its greater stock of higher qualifications compared with the other two countries.

The Effect of Structure

Differences in comparative productivity levels may also result from different structures or compositions of the manufacturing sectors. A concentration in activities with a low absolute level of value added per

U.S. = 100

Branch	Value added per hour worked	Joint factor productivity: Unadjusted for labor quality	Joint factor productivity: Adjusted for general levels	Joint factor productivity: Adjusted for vocational levels
Germany/U.S.				
Food, beverages, tobacco	69.2	59.7	60.5	59.4
Textiles, apparel, leather	87.2	72.4	72.2	71.5
Chemicals, allied products	70.6	79.4	80.8	80.9
Basic, fabricated metals	86.0	88.0	90.0	87.8
Machinery, equipment	86.0	88.3	91.6	90.0
Other manufacturing	79.1	75.3	78.1	76.8
Total manufacturing	82.2	82.5	84.7	83.4
Japan/U.S.				
Food, beverages, tobacco	33.3	45.0	44.4	n.a.
Textiles, apparel, leather	56.4	59.2	60.3	n.a.
Chemicals, allied products	75.8	87.5	88.3	n.a.
Basic, fabricated metals	82.0	81.7	82.4	n.a.
Machinery, equipment	93.2	105.2	107.6	n.a.
Other manufacturing	50.0	56.0	56.9	n.a.
Total manufacturing	67.5	75.8	77.1	n.a.

Source: Labor productivity, see table 2; joint factor productivity, see table 7; differences in labor qualifications from tables 8 and 9, weighted at 0.6 times the wage differential.
n.a. = not available.

hour worked may help explain a relative low productivity level for manufacturing as a whole in one country compared with another. This structural effect can be calculated by reweighting the manufacturing branch productivity in each country by the labor input weights of only one of the two countries. In other words, the labor force is assumed to be distributed identically among the branches in both countries. For instance, at prices and labor input weights of country X, the effect is calculated as

$$(4) \qquad PRODTY_{m(LX)}^{XU(X)} = \sum_{k=1}^{s} \frac{Y_k^{X(X)}}{L_k^X} * \frac{L_k^X}{L_m^X} \Big/ \sum_{k=1}^{s} \frac{Y_k^{U(X)}}{L_k^U} * \frac{L_k^X}{L_m^X},$$

where $PRODTY_{m(LX)}^{XU(X)}$ is relative productivity for total manufacturing be-

Table 11. Comparison of the Effect of Structure on Value Added per Hour Worked for Manufacturing Branches, 1987

U.S. = 100

Branch	*Unadjusted for structural differences*	*Adjusted at branch level*	*Adjusted at industry level*
Germany/U.S.			
Food, beverages, tobacco	69.2	n.a.	64.2
Textiles, apparel, leather	87.2	n.a.	85.4
Chemicals, allied products	70.6	n.a.	69.4
Basic, fabricated metals	86.0	n.a.	82.0
Machinery, equipment	86.0	n.a.	83.4
Other manufacturing	79.1	n.a.	76.1
Total manufacturing	82.2	78.9	76.7
Japan/U.S.			
Food, beverages, tobacco	33.3	n.a.	36.1
Textiles, apparel, leather	56.4	n.a.	54.3
Chemicals, allied products	75.8	n.a.	83.1
Basic, fabricated metals	82.0	n.a.	86.1
Machinery, equipment	93.2	n.a.	99.3
Other manufacturing	50.0	n.a.	51.3
Total manufacturing	67.5	70.1	69.7

Source: Unadjusted productivity ratios from table 2; adjustment at branch level on the basis of output and labor from tables A-3 and A-4; adjustment at industry level for Germany-U.S. based on industry matches for 50 industries, and for Japan-U.S. based on matches for 206 industries. Adjusted results are based on a geometric average of the four combinations of weighting at labor input and price weights of own country and the United States.

n.a. = not available.

tween country X and U in prices and labor input weights of country X, $Y_k^{X(X)}$ and $Y_k^{U(X)}$ are value added in branch k in country X and U, respectively, at prices of country X, L_k^X and L_k^U are the number of hours worked in branch k in country X and U, respectively, and L_m^X is the total number of hours worked in manufacturing in country X.[40]

Table 11 shows the results of these structural adjustments, which we made at two different levels. The first adjustment (second column) was made at the level of the sixteen manufacturing branches. This adjustment reduces the German productivity ratio from 82.2 percent to 78.9 percent. It appears that Germany has a relatively large share of its manufacturing activities in branches with a high absolute productivity

40. Similar formulations can be derived for any combination of labor input and price weights of country U and country X.

level, such as chemicals, metal products, and machinery and equipment. The structural effect reduces Japan's productivity gap with the United States. Japan still has a relatively large share in branches with low relative productivity levels, such as food products and textiles, and the structural adjustment increases its productivity level from 67.5 percent to 70.1 percent.[41]

The third column of table 11 show the structural effect after a more detailed adjustment, because we took the structure effect within branches into account as well. For the Germany-U.S. comparison productivity and labor input ratios were derived from the censuses for 50 industries. This structural effect for total manufacturing was slightly stronger than when measured at branch level only. The direction of adjustment was reflected at the level of all major branches; in each case the adjustment increased the productivity gap between Germany and the United States. For the Japan-U.S. comparison a breakdown of 206 industry matches was possible. It appears that substantial structural effects occurred for each of the six major manufacturing branches, particularly chemicals, basic and fabricated metals, and machinery and equipment.

After adjusting for structural effects, the labor productivity gap between Germany and the United States is only slightly smaller than that between Japan and the United States in 1987. This indicates that the better productivity performance (without such an adjustment) in Germany is partly related to the strong concentration of German manufacturing in branches and industries with relatively high absolute productivity levels.

The Effect of Plant Size

Labor productivity gaps between countries are to some extent related to differences in plant size. The production censuses used for this study include information on the distribution of value added and employment among size categories. On the whole, plants with few employees show lower value added per employee than do large plants. To a large extent

41. It is common practice to use employment shares in calculating structural effects. One could also use output shares, which slightly increases the structural effect at branch level by 1.9 percentage points for Germany (as the German-U.S. productivity ratio goes down from 78.9 to 77.0 percent) and by 1.7 percentage points for Japan (namely, from 70.1 to 71.8 percent).

Table 12. The Effect of Size Differences on Value Added per Hour Worked, Japan as a Percentage of the United States, 1987

U.S. = 100

Branch	*Unadjusted*	*Adjusted*
Food, beverages, tobacco	33.3	41.9
Textiles, apparel, leather	56.4	63.2
Chemicals, allied products	75.8	84.8
Basic, fabricated metals	82.0	92.4
Machinery, equipment	93.2	105.7
Other manufacturing	50.0	62.1
Total manufacturing	67.5	79.2

Source: Unadjusted productivity ratios from table 2; adjustment on the basis of the size distribution in the censuses of production excluding employment in auxiliary units. This ratio was applied to the productivity ratio adjusted for auxiliary units. Adjusted results are based on a geometric average of weighting at labor weights of Japan and the United States.

that difference is related to differences in capital intensity by size category.

In Japan manufacturing units with fewer than one hundred employees accounted for more than half of all manufacturing units, whereas only 30 percent of the units in the United States had fewer than one hundred employees.[42] The lowest quartile of all units in Japan had fewer than twenty employees, compared with seventy employees in the United States. Table 12 shows the effect of differences of size distribution on the Japan-U.S. comparison. The same procedure was applied as explained above for the structural adjustment; that is, value added per hour worked was weighted at the labor input weights of one of the two countries (see equation 4 above).

It appears that the relatively small size of local units in Japan accounts for a substantial part of the productivity gap, in particular in machinery and transport equipment and in other manufacturing. This effect, however, can probably not be seen independently of the somewhat lower level of capital intensity in Japanese manufacturing observed above.

We were not able to calculate the size effect for Germany, because the census estimates are for enterprises and not for local units, and because the German production census excludes information for enter-

42. The unit is a "local unit," which is a producing unit at a single postal address. The local unit is the most relevant concept for an analysis of the effect of average size on productivity, although certain economies of scale, such as those derived from large-scale administrative management, can only be obtained at activity or legal unit level.

Table 13. Comparison of the Average Median Size of Manufacturing Units by Employment, 1987

Branch	*Germany*	*Japan*	*United States*
Food, beverages, tobacco	31	52	274
Textiles, apparel, leather	112	26	233
Chemicals, allied products	723	107	240
Basic, fabricated metals	248	48	208
Machinery, equipment	889	195	633
Other manufacturing	79	28	198
Total manufacturing			
Median size	318	166	263
Average size	30	16	49

Source: See sources for size of manufacturing unit in the data appendix. Excludes auxiliary units.

prises with fewer than twenty employees. Using German labor statistics, however, we derived information on the distribution of employment by size and local unit.

Table 13 compares the average median size of local manufacturing units by major branch for the three countries in 1987. The median is the average size where half of all employees are employed in plants that are smaller and half in plants that are bigger. This measure is more suitable for analyzing productivity differences than the average number of workers per plant.

For total manufacturing the median plant size is clearly larger in Germany than in the United States, whereas the Japanese plant size is much smaller. In terms of an arithmetic average, however, the United States, and not Germany, has the largest number of employees per plant, namely, 49 compared with 30 employees. This implies that, although more than half of American manufacturing employees work in plants with fewer than 263 employees, the United States had more large plants than either of the other two countries.

The variation in median size is quite substantial among major branches. Germany had the smallest median size of the three countries in food manufacturing; for textiles and other manufacturing industries the median size in Germany was also smaller than in the United States. The fact that more than half of the employees in the chemicals group and the investment goods group work in very large plants explains the relatively high median size for Germany.

Although no estimate can be provided for the size effect on the comparative productivity performance of Germany and the United States, table 13 makes clear that an adjustment for size would increase, rather than reduce, the productivity gap between these two countries, although the effect will not be as substantial as for the Japan-U.S. comparison.

Conclusion

In this section we looked at four possible causes for the manufacturing productivity gaps between the United States and Germany and Japan, respectively. We conclude that at the level of total manufacturing, capital intensity once played an important role in narrowing the productivity gap but that it is no longer a powerful explanatory factor. Differences in labor force qualifications and structure were also not very important in 1987, although the effects of capital and skill intensity are occasionally bigger at branch level.

An adjustment for structure slightly widened the productivity gap between Germany and the United States and slightly narrowed the gap between Japan and the United States. We found a more substantial effect for size differences in the Japan-U.S. comparison. This effect is also likely to play a role in the Germany-U.S. comparison although in the opposite direction, increasing, rather than reducing, the productivity gap.

On the whole, the factors we examined appeared either to increase the labor productivity gap between Germany and the United States or to be insignificant, whereas these factors explain at least part of the original difference in labor productivity between Japan and the United States. This finding implies that, after adjusting for the factors studied here, the productivity gaps are much more of the same magnitude than they were before the adjustment.

The level accounting method applied in this section needs to be developed further to make it a more accurate tool in explaining cross-country productivity differentials. First, some additional factors, which are looked at in traditional growth accounting studies, need to be considered here as well. Potential candidates for further analysis are differences in the age-gender structure of the manufacturing labor force and the effects of the adoption of new technology. For the latter, indicators of expenditure on research and development or the effects of patents can be analyzed. Recent studies found that privately funded R&D investment has a significant positive effect on productivity growth, although in a cross-country level comparison, the factor share of R&D is likely to be well below 10 percent if a production function with constant returns to scale is used.[43]

Finally, we did not take account of possible interaction effects between the various factors. These may, for example, be important in relation to the effects of capital intensity on the one hand and size and structure on the other. Furthermore, differences in the degree of embodied technology in the capital stock installed in the countries need to be assessed more carefully than was possible in the framework of this paper.

Summary and Concluding Remarks

In this paper we applied the industry-of-origin approach to international comparisons of output and productivity levels in manufacturing for Germany, Japan, and the United States during the postwar period. Unit value ratios, based on the quantities and ex-factory sales value of matched product items, were compiled to convert the output value by manufacturing branch in national currencies to a common currency. It appears that the diversity in unit value ratios across branches is quite substantial, particularly in the Japan-U.S. comparison. Branch-specific unit value ratios, instead of GDP or proxy PPPs, are therefore crucial in determining the relative productivity performance across branches. For a more disaggregated analysis at industry level, it will be necessary to consider the effect of quality differences and double deflation, but at the level of major branches (with the exception of the need for double deflation in food manufacturing), these effects are not so great as to seriously affect our results.

We found that up to the early 1980s the manufacturing sectors of Germany and Japan performed in accordance with the catch-up and convergence hypothesis on relative productivity levels. Since then, however, the productivity gap between Germany and the United States

43. See, for example, Lichtenberg (1992b).

has significantly increased. After a brief slowdown during the first half of the 1980s, Japan continued to improve its relative productivity standards vis-à-vis the United States. In some major branches, in particular machinery and transport equipment, Japan is now clearly the productivity leader. Because the Japanese productivity performance in some other branches such as food manufacturing is still much worse than in the United States, Japan and the United States are likely to share productivity leadership in manufacturing for some time to come.

We also looked at four possible factors that could explain part of the productivity gap. It appears that at the level of total manufacturing, the role of differences in relative capital intensity, skill intensity, and composition of the sector was quite small by 1990. For the six major branches in manufacturing, however, we occasionally found more substantial effects. The average median size of manufacturing units was largest in Germany and smallest in Japan. An adjustment for size differences therefore increased Japan's relative productivity performance.

We conclude that part of the productivity gaps that still exist between the countries has to be explained by factors of a broader nature than those analyzed here. These broad factors cover a wide range from sociopolitical and institutional differences to the effects of rent seeking, bargaining outcomes, and economic policies. The effects of such factors can differ widely between branches and industries and can be related to the organizational structure of the industry, to the degree of international competitiveness that the industry faces, and to differences in the effect of government regulations on quality, safety, and environmental standards. To assess the impact of such factors, more detailed industry studies are required, for which this study can perhaps serve as a reference point for the aggregate picture.

Appendix

Following are the sources and methods the authors used in their paper.

Real Output in Manufacturing

The series for real output in manufacturing were derived from the national accounts for Germany (from 1960 onward), Japan (from 1955 onward), and the United States (for the whole period). For earlier years (Germany from 1950 to 1960; Japan from 1950 to 1955), we used production indexes for real output.

The original manufacturing GDP series is expressed in market prices of a recent year, namely, 1985 for Germany and Japan and 1982 for the United States. The German and Japanese national accounts use weights that are shifted at regular intervals (mostly every five years), but the U.S. national accounts use fixed weights for the whole period.

Apart from its use of fixed weights, the U.S. national accounts series on manufacturing has been also criticized for, among other things, its use of an inadequate double deflation procedure and the inclusion of a statistical adjustment factor to make the double deflated results consistent with the rest of the national accounts. Although complete revisions of the manufacturing GDP series are not yet available, the Bureau of Economic Affairs (BEA) recently completed and published some of the revisions back to 1977.[44]

Germany: 1950–60 based on index of net production from Statistisches Bundesamt, *Lange Reihen zur Wirtschaftsentwicklung 1974*, Wiesbaden, 1974; 1960–70 from Statistisches Bundesamt, *Volkswirtschaftliche Gesamtrechnungen, Revidierte Ergebnisse 1950–1990*, Wiesbaden, 1991; 1970–90 from Statistisches Bundesamt, *Volkswirtschaftliche Gesamtrechnungen, Konten und Standardtabellen 1991*, Wiesbaden, 1992.

Japan: 1950–53 based on production index from Kazushi Ohkawa and Miyohei Shinohara, *Patterns of Japanese Economic Development: A Quantitative Appraisal*, Yale University Press, New Haven, 1979; 1953–55 based on Kazushi Ohkawa and Henry Rosovsky, *Japanese Economic Growth*, Stanford University Press, Stanford, 1973; 1955–89 based on Economic Planning Agency (EPA), *Report on National Accounts from 1955 to 1989*, Tokyo, 1991; 1990 from EPA, *Annual Report on National Accounts 1993*, Tokyo, 1993.

United States: 1950–87 at 1982 fixed weights from U.S. Department of Commerce, *National Income and Product Accounts of the United*

44. For the most explicit criticism of the U.S. national accounts output series in recent years, see Mishel (1988) and Denison (1989). For a defense see Lawrence (1991). Revisions were published and discussed in U.S. Department of Commerce, *Survey of Current Business*, January and April 1991 and May 1993.

States, 1929–1982, Washington, D.C., 1986, and U.S. Department of Commerce, *Survey of Current Business*, Washington, D.C., January and April 1991; 1987–90 from *Survey of Current Business*, May 1993.

Number of Persons Engaged in Manufacturing

Germany: 1950–70 based on Statistisches Bundesamt, *Lange Reihen zur Wirtschaftsentwicklung 1974*, Wiesbaden, 1974; 1970–90 from Statistisches Bundesamt, *Volkswirtschaftliche Gesamtrechnungen, Konten und Standardtabellen 1991*, Wiesbaden, 1992. The figures are for all employees (''Erwerbstätige'').

Japan: 1950–55 based on Statistics Bureau, Management and Coordination Agency, *Labor Force Survey*, Tokyo, various issues; 1955–89 based on EPA, *Report on National Accounts from 1955 to 1989*, Tokyo, 1991; 1990 from EPA, *Annual Report on National Accounts 1993*, Tokyo, 1993; industry breakdown for some branches adjusted with employment from Ministry of International Trade and Industry (MITI), *Census of Manufactures, Report by Industries*, Tokyo, various issues.

United States: U.S. Department of Commerce, *National Income and Product Accounts of the United States, 1929–1982*, Washington, D.C., 1986; U.S. Department of Commerce, *National Income and Product Accounts of the United States, vol. 2, 1959–1988*, Washington, D.C., 1992; and U.S. Department of Commerce, *Survey of Current Business*, Washington, D.C., various issues. The U.S. figures are for all persons engaged and are derived as the sum of full-time and part-time employees and self-employed persons.

Annual Working Hours

For all three countries annual working hours are derived as hours actually worked and exclude paid hours that are not worked due to holidays, sickness, and other absences.

Germany: 1950–60 based on Statistisches Bundesamt, *Lange Reihen zur Wirtschaftsentwicklung 1974*, Wiesbaden, 1974; 1960–86 from H. Kohler and L. Reyher, *Arbeitszeit und Arbeitsvolumen in der Bundesrepublik Deutschland, 1960–1988*, Institut für Berufsforschung, Nürnberg, 1988; updated to 1990 with series from Deutsches Institut für Wirtschaftsforschung, *Produktionsvolumen und -potential, Produktionsfaktoren des Bergbaus und des Verarbeitendes Gewerbe*, Berlin, 1991.

Japan: Ministry of Labor, *Monthly Report on the Labor Force Survey*, Tokyo, various issues, weighted with employment by branch, as given above.

United States: Weekly hours paid from Bureau of Labor Statistics (BLS), *Employment, Hours and Earnings, United States, 1909–1990*, BLS Bulletin 2370, Washington, D.C., 1991; adjusted to hours worked with ratios of hours at work to hours paid from Mary Jablonski, Kent Kunze, and Phyllis F. Otto, ''Hours at Work: A New Base for BLS Productivity Statistics,'' *Monthly Labor Review*, 113, pp. 17–34, Washington, D.C., February 1990. 1989 and 1990 from tabulations provided by BLS.

Estimating Gross Capital Stock in Manufacturing

Stocks of machinery and equipment and structures can be calculated on the basis of the perpetual inventory method (PIM), as pioneered by Raymond Goldsmith.[45] This method depends on the availability of series on investment, which are cumulated and scrapped on the basis of assumptions concerning asset lives and retirement patterns.

For this study we did not use the official capital stock estimates for each country because the comparability of the estimates across countries is weak. The German and U.S. series are based entirely on a PIM, but the Japanese estimates also make use of wealth surveys.[46] Furthermore, each country applies its own assumptions on asset lives and scrapping patterns. In some cases these assumptions are derived from an ad hoc sample survey, but more often they are based on tax records, company accounts, or expert advice. As a result machinery in Japanese manufacturing is, for example, assumed to last for eleven years, compared with nineteen years in the United States, and the lifetime of all manufacturing assets in Germany is taken to be forty-one years, compared with thirty-two years in the United States.

Because there is little hard evidence for such large differences in

45. Goldsmith (1951).

46. See Dean, Darrough, and Neef (1990) for a discussion.

asset lives and scrapping patterns, we compiled our own capital stock estimates on the basis of the PIM using "standardized" assumptions on asset lives and the retirement of the assets. The standardized service lives are based on an average of the assumed lives for fourteen OECD countries, which we derived from a detailed OECD survey.[47] On this basis we applied a service life of forty-five years to investment in nonresidential structures in manufacturing and seventeen years to investment in equipment and vehicles used in manufacturing. We assumed that assets were retired on the basis of a "delayed linear" retirement pattern, which implied that structures are scrapped proportionally, between thirty-six and fifty-four years, and that equipment and vehicles (taken together) are scrapped between fourteen and twenty years.[48]

Because of the lack of long-run investment data, we were not able to calculate our own PIM estimates for major branches. As a proxy we therefore derived the share of the major branches in total manufacturing according to the official estimates, which we applied to our own estimates for total manufacturing.

The conversion of the capital stock estimates to U.S. dollars was done on the basis of Fisher PPPs for 1985 for capital formation in machinery and equipment and structures, which were supplied by Eurostat.

Sources on Investment Series for Total Manufacturing and Capital Stock Breakdown by Sector

Germany: Investment before 1960 from W. Kirner, *Zeitreihen für das Anlagevermögen der Wirtschaftsbereiche in der Bundesrepublik Deutschland*, Deutsches Institut für Wirtschaftsforschung, Berlin,

47. OECD (1993).

48. See Maddison (1993) for a detailed assessment of the comparability of capital stock across countries and long-run series for the total economy for six OECD countries (France, Germany, Japan, the Netherlands, the United Kingdom, and the United States). See van Ark (forthcoming) for a more detailed account of the manufacturing capital stock estimates for the same countries. Blades (1993) criticizes the standardization of asset life assumptions across countries. At an aggregate level, different asset lives may, of course, arise from differences in the composition of assets. This argues in favor of a more disaggregated approach to obtain capital stock estimates on the basis of PIM than was possible in the framework of this study.

1968; 1960–88 from Statistisches Bundesamt, *Volkswirtschaftliche Gesamtrechnungen, Revidierte Ergebnisse 1950–1990*, Wiesbaden, 1991; 1989 and 1990 years from *Volkswirtschaftliche Gesamtrechnungen*, recent issues. The breakdown of the capital stock over branches for 1970–90 was based on Statistisches Bundesamt, *Volkswirtschaftliche Gesamtrechnungen, Revidierte Ergebnisse 1950–1990*, Wiesbaden, 1991; 1950 and 1960 were based on Heinrich Lützel, "Estimates of Capital Stock by Industries in the Federal Republic of Germany," *Review of Income and Wealth*, 23 (March) 1977.

Japan: Investment series before 1954 from Ohkawa and Rosovsky (1973), and Ohkawa and Shinohara (1979); 1954 to 1965 from MITI, *Census of Manufactures, Report by Industries*, Tokyo, various issues, deflated with price indexes from Bank of Japan, *Price Indexes Annual*, Tokyo, various issues; 1965–90 from EPA, *Gross Capital Stock of Private Enterprises*, Tokyo, 1991 and 1993 issues, and distributed between machinery and equipment and structures on the basis of the census. Breakdown of capital stock over branches for 1965–90 based on EPA (1991, 1993), 1955 based on Administrative Management Agency, *1970 Input-Output Tables: Fixed Capital Stock Matrices* (data for 1955); 1960 based on Kimio Uno, *Japanese Industrial Performance*, North-Holland, Amsterdam, 1987.

United States: Investment from U.S. Department of Commerce, *Fixed Reproducible Tangible Wealth in the United States, 1925–1985*, 1986; recent years from BEA Wealth Data Tape; sectoral breakdown based on U.S. Department of Commerce, *Fixed Reproducible Tangible Wealth in the United States, 1925–1989*, 1993; 1990 from U.S. Department of Commerce, *Survey of Current Business*, January 1992.

The Quality of the Manufacturing Labor Force

The estimates of qualification levels of the labor force are based on the labor force and population surveys in each country.

General qualification levels in Germany were distributed on the basis of the American classification scheme by assuming that qualifications at the level of "(Volks)Hauptschule" were equivalent to elementary and high school qualifications, "Realschule" to junior college level, and "(Fach)Hochschule" to senior college and university. German vocational qualifications were distributed by putting "Angelernte" and "Lehrberuf" in lower intermediate qualifications, "Meister" and "Techniker" in upper intermediate qualifications, and "Fachhochschule" and "Hochschule" in higher vocational qualifications.

The classification of vocational qualifications in the United States was much cruder, because the population survey does not distinguish between general and vocational qualifications. Estimates from a survey for 1963 show that about 37.5 percent of the labor force received some kind of vocational training at the high school level.[49] On the assumption that the time spent on vocational subjects by this 37.5 percent of all working people attending high school was about one-third of all education received, we classified 12.5 percent of the 1987 labor force with high school diplomas as having intermediate vocational qualifications. Furthermore, we included half of junior college graduates in the segment of intermediate vocational qualifications and the other half in "no vocational qualifications." U.S. higher qualifications are senior college and university.

Germany: Statistisches Bundesamt, *Mikrozensus 1987*, Special Tabulations, kindly provided by Mary O'Mahony and Karin Wagner.

Japan: Ministry of Labor, *Basic Survey on the Wage Structure 1987*, Tokyo, 1988.

United States: Unpublished tabulations from U.S. Department of Labor, "Educational Attainment of Workers, March 1987."

49. See Daly (1984, p. 236).

Table A-1. Unit Value Ratios, Percentage of Matched Sales, and Number of Matched Items by Manufacturing Branch, Germany/United States, 1987

	Unit value ratio (DM/US$)			*Percent of matched sales*		
Branch	*U.S. quantity weights (1)*	*Germany quantity weights (2)*	*Geometric average (3)*	*Germany (4)*	*U.S. (5)*	*Number of UVRs (6)*
Food manufacturing	1.98	1.92	1.95	44.04	35.92	43
Beverages	2.59	2.38	2.48	58.85	38.41	11
Tobacco products	1.20	1.23	1.21	69.29	82.23	1
Textiles	2.69	2.52	2.61	39.64	59.68	21
Wearing apparel	2.92	2.90	2.91	56.93	39.71	27
Leather products, footwear	2.85	2.76	2.80	64.38	53.14	11
Wood, furniture, fixtures	2.83	2.57	2.70	30.76	16.11	13
Paper, printing	2.28	2.23	2.26	18.63	23.67	13
Chemical products	2.66	2.47	2.56	11.80	12.87	17
Petroleum, coal products	1.96	1.98	1.97	25.02	76.04	5
Rubber, plastic products	2.33	2.31	2.32	7.68	8.71	4
Stone, clay, glass	2.11	1.88	1.99	18.94	23.03	13
Basic, fabricated metals	2.25	2.16	2.20	46.49	23.89	31
Machinery, transport equipment	2.49	2.49	2.49	13.83	11.56	40
Electric machinery	1.87	1.92	1.90	29.61	20.97	21
Other manufacturing	2.25	2.16	2.21	0.00	0.00	0
Total manufacturing	2.25	2.16	2.21	24.36	24.82	271

Sources: Statistisches Bundesamt, *Produktion im Produzierenden Gewerbe 1987*, Wiesbaden, 1988; U.S. Department of Commerce, Bureau of the Census, *1987 Census of Manufactures, Industry Series*, Washington, D.C., 1990.

Table A-2. Unit Value Ratios, Percentage of Matched Sales, and Number of Matched Items by Manufacturing Branch, Japan/United States, 1987

	Unit value ratio (Yen/US$)			*Percent of matched sales*		
Branch	*U.S. quantity weights (1)*	*Japan quantity weights (2)*	*Geometric average (3)*	*Japan (4)*	*U.S. (5)*	*Number of UVRs (6)*
Food manufacturing	258.5	274.1	266.2	13.71	11.21	16
Beverages	208.3	207.8	208.1	32.73	30.21	3
Tobacco products	113.3	113.3	113.3	86.00	80.68	1
Textiles	178.6	184.8	181.7	25.85	38.87	14
Wearing apparel	185.8	172.9	179.2	21.20	30.38	9
Leather products, footwear	212.6	205.3	208.9	34.12	29.30	4
Wood, furniture, fixtures	478.2	464.9	471.5	19.52	7.86	2
Paper, printing	186.4	189.9	188.1	13.05	15.04	10
Chemicals	241.3	218.3	229.6	15.53	14.20	31
Petroleum, coal products	284.6	222.5	251.6	64.93	76.64	6
Rubber, plastic products	125.2	117.6	121.3	7.37	11.44	6
Stone, clay, glass	194.2	184.5	189.3	32.97	27.75	9
Basic, fabricated metals	193.7	164.4	178.4	24.92	22.94	34
Machinery, transport equipment	160.8	97.2	125.0	20.28	17.69	26
Electric machinery	152.0	133.9	142.6	11.49	11.06	18
Other manufacturing	202.9	148.5	173.6	0.00	0.00	0
Total manufacturing	202.9	148.5	173.6	19.10	19.86	190

Sources: MITI, *Census of Manufactures 1987, Report by Commodities*, Tokyo, 1989, and MITI, *Census of Manufactures 1987, Report by Industries*, Tokyo, 1989; Bureau of the Census, *1987 Census of Manufactures, Industry Series*, 1990.

Table A-3. Value Added, Labor Input, and Comparative Labor Productivity, Germany and the United States, 1987

	Germany[a]			United States[a]			Germany/U.S. (%)	
Branch	*Census value added at factor cost (mln. DM)*	*Employees (000s)*	*Annual hours worked per employee*	*Census value added at factor cost (mln. $)*	*Employees (000s)*	*Annual hours worked per employee*	*Census value added per employee*[a]	*Census value added per hour worked*[a]
Food manufacturing	36,018	363.8	1,889	95,349	1,319.6	1,893	70.2	70.3
Beverages	12,781	87.3	1,585	21,961	165.9	1,866	44.5	52.4
Tobacco products	3,483	16.8	1,585	14,252	63.1	1,853	75.6	88.3
Textiles	15,928	222.0	1,606	24,861	681.1	2,053	75.4	96.4
Wearing apparel	9,529	171.7	1,557	29,808	1,029.3	1,794	65.9	75.9
Leather products, footwear	3,317	54.6	1,621	4,155	128.0	1,843	66.8	76.0
Wood, furniture, fixtures	16,906	214.3	1,728	42,614	1,045.4	1,964	71.8	81.5
Paper, printing[b]	29,859	293.4	1,666	82,678	1,311.9	1,847	71.6	79.4
Chemicals	87,414	592.6	1,627	116,030	980.1	1,922	48.6	57.4
Petroleum, coal products	8,027	30.9	1,663	17,223	144.6	1,922	110.7	127.9
Rubber, plastic products	28,760	325.7	1,621	42,080	811.2	1,986	73.3	89.8
Stone, clay, and glass	23,163	239.4	1,726	29,508	479.7	2,003	79.1	91.8
Basic, fabricated metals	82,949	973.8	1,587	113,481	2,048.6	1,956	69.8	86.0
Machinery, transport equipment	191,645	1,969.5	1,624	244,040	3,690.5	1,905	77.5	90.9
Electrical machinery	91,085	1,019.4	1,550	93,385	1,636.4	1,877	62.8	76.1
Other manufacturing	14,667	192.3	1,612	83,080	1,323.3	1,885	55.1	64.4
Total manufacturing	655,529	6,767.6	1,630	1,054,503	16,858.7	1,909	70.2	82.2

Sources: Statistisches Bundesamt, *Produzierende Gewerbe, Kostenstruktur der Unternehmen 1987*, Reihe 4.3.1 to 4.3.3; hours from H. Kohler and C. Reyher, *Arbeitszeit und Arbeitsvolumen in der Bundesrepublik Deutschland, 1960–1986*, Institut für Arbeitsmarkt und Berufsforschung, Nürnberg 1988, updated to 1987 with data from Deutsches Institut für Wirtschaftsforschung, *Produktionsvolumen und -potential, Produktionsfaktoren des Bergbaus und des Verarbeitendes Gewerbe*, Berlin, 1991; United States from Bureau of the Census, *1987 Census of Manufactures General Summary*, 1990; hours worked from BLS, *Monthly Labor Review*, various issues, adjusted to actual hours worked with ratios from BLS, "Ratios of Hours at Work to Hours Paid for Production and Nonsupervisory Employees, 1981–1988."

a. Excludes establishments with fewer than twenty employees.

b. Excludes publishing.

Table A-4. Value Added, Labor Input, and Comparative Labor Productivity, Japan and the United States, 1987

	Japan			*United States*			*Japan/U.S. (%)*	
Branch	*Census value added at factor cost (bln. yen)*	*Employees (000s)*	*Annual hours worked per employee*	*Census value added at factor cost (mln. $)*	*Employees (000s)*	*Annual hours worked per employee*	*Census value added per employee*	*Census value added per hour worked*
Food manufacturing	8,181	1,207.6	2,126	99,018	1,384.9	1,893	35.6	31.7
Beverages	1,733	110.0	2,126	22,585	172.2	1,866	57.7	50.6
Tobacco products	270	18.2	2,126	14,264	63.5	1,853	58.3	50.8
Textiles	3,366	739.8	2,183	25,660	698.9	2,053	68.2	64.1
Wearing apparel	1,984	693.1	2,131	32,516	1,113.8	1,794	54.7	46.1
Leather products	438	93.5	2,148	4,378	135.7	1,843	69.5	59.6
Wood, furniture, fixtures	3,135	590.3	2,270	48,975	1,235.1	1,964	28.4	24.6
Paper, printing	8,328	1,010.9	2,226	140,651	2,232.9	1,847	69.5	57.7
Chemicals	10,163	506.2	2,021	120,778	1,028.4	1,922	74.5	70.8
Petroleum, coal products	1,340	47.3	2,040	18,518	153.6	1,922	93.3	87.9
Rubber, plastic products	4,962	623.3	2,101	44,437	863.3	1,986	127.5	120.5
Stone, clay, and glass	4,771	531.4	2,203	33,383	554.3	2,003	78.8	71.6
Basic, fabricated metals	13,729	1,546.4	2,185	121,078	2,228.9	1,956	91.6	82.0
Machinery, transport equipment	23,169	2,431.9	2,208	255,264	3,966.1	1,905	118.4	102.2
Electrical machinery	14,518	1,905.9	2,125	95,815	1,689.4	1,877	94.2	83.2
Other manufacturing	3,625	649.8	2,076	88,428	1,429.9	1,885	52.0	47.2
Total manufacturing	103,711	12,705.6	2,161	1,165,747	18,950.9	1,909	76.4	67.5

Sources: Japan from MITI, *Census of Manufactures, Report by Industries*, Tokyo, 1989, with adjustment for employment in auxiliary units, based on ratio of employees in establishments characterized as "offices" and "business outlets" to establishments representing a "factory, workshop, and mining station" and "establishments having outlook of ordinary dwelling house," from Statistics Bureau, Management and Coordination Agency, *1986 Establishment Census of Japan*, Tokyo, 1987; hours worked from Ministry of Labour, *Monthly Labour Survey*, various issues. U.S. from sources quoted in table A-3.

Comments and Discussion

Comment by Dale Jorgenson: The theme of the paper by Bart van Ark and Dirk Pilat is an extremely important one for trade policy. Although the links between productivity and international competitiveness are well understood at a conceptual level, official data on productivity are inappropriate for assessments of competitiveness. As a consequence, the discussion of trade policy often takes place without the benefit of even the most rudimentary information about the sources of changes in competitiveness.

Because the U.S. trade balance has moved from surplus to deficit with both Germany and Japan during the postwar period, economic journalists have naturally assumed that U.S. competitiveness has deteriorated. A large literature developed during the 1980s, presenting a broad panoply of mainly fanciful ideas about the alleged decline in U.S. competitiveness and its role in the determination of the U.S. trade balance. According to comparisons of prices and manufactured products for Germany, Japan, and the United States, however, the United States has *gained* very substantially in international competitiveness, relative to Germany and Japan, over the postwar period.

Since the Smithsonian agreements of 1970, changes in the international competitiveness of German, Japanese, and U.S. industries have strongly favored the United States. These changes have been driven primarily by rapid appreciation of the yen-dollar and mark-dollar exchange rates and, secondarily, by the relative growth of wage rates in the three countries. In periods affected by increases in petroleum prices, such as 1973 and 1979, changes in these prices were also a force undercutting Japanese and, to a lesser extent, German competitiveness.

The decline in petroleum prices from 1981 to 1986 and the substantial appreciation of the U.S. dollar temporarily strengthened the competitive positions of both Germany and Japan. Renewal of depreciation of the dollar after 1985 has helped to restore the U.S. competitive position, however.

An important implication of the finding by van Ark and Pilat is that relative productivity levels in the three countries have moved in the *opposite* direction. This is brought out in table 4, giving value added per hour worked for the period 1950–90, and in table 7, giving value added per "joint unit" of labor and capital for the same period. German productivity relative to the United States roughly doubled between 1950 and 1980 but has lost ground since then. Japanese productivity doubled relative to the United States between 1950 and 1973, but Japanese gains have moderated during the past two decades.

By 1990 Germany and Japan had emerged as laggards in productivity, relative to the United States. For example, manufacturing productivity in both countries fell below that in the United States by about 20 percent. This finding received front page coverage from the *New York Times* when it was first reported in a somewhat different form by the McKinsey Global Institute.[1] Readers of the business press are still bombarded with anecdotal evidence of the low level of U.S. productivity relative to Germany and Japan. In fact Japan has been touted as the world's leader in productivity so regularly that the Japanese media have begun to believe it. This has led to a literature, mainly in Japanese, rationalizing the inferiority of U.S. productive performance.

The origin of confusion in the media is that productivity measurement is far from a settled matter among economists. For decades there have been two competing approaches to the measurement of productivity—one based on income, and the other on product. A very useful comparison of the two approaches has been given by Charles Hulten, who points out that national income is best regarded as a measure of present and future consumption opportunities, while national product provides the appropriate point of departure for productivity measurement.[2] This approach is used in a rapidly increasing proportion of the

1. Sylvia Nasar, "U.S. Output per Worker Called Best," *New York Times*, October 13, 1992, p. D1.
2. Hulten (1992).

empirical literature, including the paper of van Ark and Pilat. A shrinking number of productivity analysts still utilize income, however.[3]

The critical issue in linking productivity to international competitiveness is the definition of output for individual industries. The older literature on productivity measurement, especially that associated with the work of John Kendrick, uses the concept of value added as a measure of industry output.[4] Value added is defined as the difference between the value of gross output and the value of intermediate inputs. The value added measure of industry output has the convenient property that national product is an arithmetic sum of industry-level measures of value added. By "simplifying" productivity measurements, however, the value added approach severs the connection between productivity and international competitiveness.

One of the most important advances in industry-level productivity measurement has been to use gross output rather than value added as a measure of product at the industry level.[5] Industry output is especially advantageous for international comparisons because measures of competitiveness are based on product prices rather than on prices of value added. Another advantage of industry output is that intermediate inputs can be treated symmetrically with inputs of capital and labor services in measuring productivity. These important advantages are acquired at some cost, however, because a fully satisfactory implementation requires the integration of interindustry accounts with national income and product accounts for each of the countries involved in an international comparison.

Masahiro Kuroda and I have employed industry-level gross outputs in comparisons of productivity between Japan and the United States.[6] For this purpose we have developed annual time series of interindustry accounts in current and constant prices for both Japan and the United States. We have supplemented these data with extensive information

3. See, for example, Baily and Schultze (1991); Denison (1962, 1989); and Solow (1957, 1988).

4. Kendrick (1975). This approach has been adopted as the basis for industry-level data sets for industrialized countries discussed by Englander and Mittelstadt (1988).

5. See Jorgenson (1990).

6. See Jorgenson and Kuroda (1992). Earlier results were presented in our joint paper with Mieko Nishimizu (1987). Conrad and Jorgenson (1985) have presented trilateral comparisons for Germany, Japan, and the United States, using data for Japan and the United States from the study of Jorgenson, Kuroda, and Nishimizu.

on labor and capital inputs for both countries. Completion of this arduous task is essential for relating productivity to international competitiveness.

Unfortunately, van Ark and Pilat have based their international comparisons of productivity on the "industry-of-origin" method described in their paper. This obsolete methodology is based on value added rather than on gross output. To arrive at international comparisons of value added, it is necessary to introduce the prices of inputs of intermediate goods as well as product prices. Van Ark and Pilat, however, have chosen to ignore the prices of intermediate goods altogether. This accounts for the lack of any direct connection between their productivity comparisons and indicators of international competitiveness.

To justify the omission of intermediate goods prices from their comparisons, van Ark and Pilat appeal to the "adjusted single indicator" method of Paige and Bombach, where the single indicator is gross output.[7] The assumption of this method is that prices of value added are identical to those of gross output. This assumption is sharply at variance with the evidence presented in table 2 of the paper, comparing value added for the food industry in Japan and the United States with and without introducing prices of intermediate goods. Value added for Japan is 23.4 percent of the U.S. level for 1987, using the single indicator method, while it is 30.9 percent, using the "double deflation" method incorporating prices of intermediate goods. This fails to inspire confidence in the authors' conclusion that their method is "sufficiently robust for the purpose."

Van Ark and Pilat's assumption that prices of gross output and value added are the same is also employed in comparisons of manufacturing productivity over time for Germany, Japan, and the United States. This assumption entails the related proposition that prices of intermediate goods are the same as those of output. The plausibility of this proposition can be judged in light of the dramatic rise and fall of energy prices during the 1970s and 1980s, because energy comprises an important component of intermediate input in all of the manufacturing industries they consider. Moreover, intermediate inputs make up more than half the value of manufacturing output, so that assumptions of this

7. Paige and Bombach (1959).

type, no matter how clearly stated, are never an adequate substitute for empirical measurements.

After measures of output have been constructed for individual industries, the next problem is to link the results for different countries. This requires purchasing power parities for outputs. At the aggregate level purchasing power parities for outputs are well established in the official statistics, thanks to the work of Kravis, Heston, and Summers.[8] The most recent studies, coordinated by Eurostat and the Organization for Economic Cooperation and Development (OECD), are much more detailed than the original studies by Kravis and his associates.[9] These purchasing power parities, however, are based on purchasers' prices rather than the producers' prices required for output comparisons at the industry level.

Kuroda and I have transformed the purchasers' prices to producers' prices for Japan and the United States, using interindustry accounts for both countries to eliminate trade and transportation margins and indirect taxes. A similar approach, employed by the McKinsey Global Institute, produces results that differ "substantially" from the unit value ratios (UVRs) employed by van Ark and Pilat. The UVRs are preferable, in principle, because they represent ratios of producers' prices for the two countries being compared. For the United States the underlying data source provides prices for 11,000 products; for Germany and Japan prices are available for 6,000 and 1,850 items, respectively.

The difficulty with the exploitation of unit values for international comparisons is that items for which prices are available must be matched between countries. Van Ark and Pilat could match only 271 items for Germany and the United States, and these cover less than a quarter of manufacturing output, while the 190 matched items for Japan and the United States cover an even smaller proportion of output in the two countries. These "matches" are extended to all manufacturing output by a tortuous and highly implausible series of assumptions. The practical disadvantages of UVRs largely outweigh their conceptual advantages, so the purchasing power parities of Kravis and his associates, combined with internationally comparable interindustry accounts, are far more satisfactory.

8. Kravis, Heston, and Summers (1982).

9. See, for example, OECD (1992).

Another issue that arises in productivity measurement is the comparison of labor inputs between countries. Official statistics are not much help in resolving the issues. For example, data from the U.S. Bureau of Labor Statistics employed by van Ark and Pilat are based on unweighted hours worked as a measure of labor input. This measure is highly inappropriate for international comparisons, however, because it ignores substitution among different types of labor inputs. Hours worked for each type of labor must be weighted by the corresponding marginal product to capture this substitution. Because labor force composition by characteristics such as age, sex, and educational attainment of workers differs substantially among Germany, Japan, and the United States, this is a fundamental issue in comparing labor inputs among the three countries.

Assessments of international competitiveness require estimates of purchasing power parities for labor inputs of the type that Kuroda and I have constructed for Japan and the United States, taking account of the differences in the composition of the labor forces in the two countries by age, sex, and education. Comparisons of labor inputs over time for a given country also require detailed breakdowns of labor input by these characteristics. In Germany, Japan, and the United States, the educational qualifications of the labor force have been substantially upgraded, and important changes have occurred in age and sex composition as well. The unweighted measures of hours worked used in official statistics are inappropriate for comparisons over time.

All of the comparisons of productivity over time for Germany, Japan, and the United States presented by van Ark and Pilat are limited to measures of labor input based on employment or hours worked. They have chosen to ignore empirical evidence accumulated over three decades of productivity measurement that changes in the composition of the labor force are very important sources of growth in labor input. The comparisons among labor inputs for Germany, Japan, and the United States for the year 1987, presented by van Ark and Pilat in table 10 of their paper, incorporate differences in educational attainment. The authors, however, reduce industry differences for both Germany and Japan, relative to the United States, by an arbitrary 40 percent for all six industries included in their study to reflect the omission of age, sex, and other differences in labor force composition.

A similar issue arises for a capital input. Capital goods differ substantially in marginal productivity. To account for substitutions among different types of capital inputs, each capital good must be weighted by its marginal product. For this purpose it is necessary to focus on the flow of capital services rather than the stock of capital. Marginal products must be broken down by legal form of organization and class of asset. Comparisons between countries require purchasing power parities for different types of capital input such as those Kuroda and I have constructed for Japan and the United States.

Important progress has been made in measuring capital input in the U.S. official statistics compiled by the Bureau of Labor Statistics. Unfortunately, the traditional approach—used by Denison, Kendrick, and Solow[10]—uses unweighted capital stocks. Productivity comparisons between countries or between different time periods for a given country, such as those of van Ark and Pilat, do not adequately account for substitutions among different types of capital inputs. This results in a highly distorted view of capital as a source of economic growth and a contributor to differences in production levels between countries.

The research required for productivity comparisons relevant to international competitiveness poses formidable challenges for economists. These comparisons require a system of national accounts for each country that successfully integrates interindustry accounts with national income and product accounts. Even for Japan and the United States, two countries with highly developed statistical systems, productivity comparisons have required the development of new data bases for output and for intermediate, capital, and labor inputs. Extending productivity comparisons to Germany poses many additional problems. Finally, data for these countries must be linked, using purchasing power parities.

The international comparisons of productivity presented by van Ark and Pilat are very far from state of the art. However, their conclusion that relative productivity levels have moved in precisely the opposite direction from changes in competitiveness will undoubtedly survive the infusion of more up-to-date methodology and more satisfactory data. International competitiveness has changed very rapidly under the post-Smithsonian regime of floating exchange rates, and these changes have been driven by exchange rate changes. With wildly fluctuating ex-

10. See Jorgenson (1989) for detailed comparisons of the Denison and Kendrick approaches with the capital input approach. The traditional approach has been implemented for OECD countries by Englander and Mittelstadt (1988).

change rates, relative productivity movements are simply too slow to affect competitiveness substantially over periods as short as one or two decades.

The conclusion by van Ark and Pilat that Germany and Japan have emerged as productivity laggards, despite impressive growth in productivity during the 1960s and 1970s, should no longer surprise economists. This conclusion, however, has far-reaching implications for the literature on the U.S. decline in technology, summarized, for example, by Richard Nelson and Gavin Wright.[11] Economists have miseducated a whole generation of technologists, who regularly extol advances in technology in Germany and Japan, overlooking the rapid development of U.S. technology, and support their anecdotal evidence of German and Japanese superiority by appealing to the deterioration of the U.S. trade balance.

Economists face an uphill battle in selling the position that the decline in the U.S. trade balance is, first and foremost, an issue in macroeconomics. The notion that the saving-investment identity is relevant to understanding the implications of monetary and fiscal policy for the trade balance is simply too remote from ordinary discourse to be readily intelligible to a lay audience. Empirical studies like that of van Ark and Pilat will help to raise the level of professional discussion. Even economists who are not remotely interested in the details of productivity measurement will be able to appreciate the importance of the authors' findings on relative productivity growth.

Comment by Frank R. Lichtenberg: In this paper Bart van Ark and Dirk Pilat measure, and attempt to explain, differences among American, German, and Japanese productivity *levels* during the past forty years. The U.S. Bureau of Labor Statistics (BLS) publishes official comparative international productivity data, but BLS reports only *growth rates,* not levels, of nations' productivity. There is, therefore, a clear need for the kind of research performed in this paper. At the same time, the reluctance of BLS to make comparisons of productivity levels signals that there are major difficulties in doing so.

Labor productivity is defined as real output Q divided by labor input. Accurate measurement of productivity therefore requires accurate mea-

11. See Nelson and Wright (1992); and Arrison and others (1992).

surement of real output. In principle Q can be measured in two equivalent ways: direct—the approach used by van Ark and Pilat—and indirect. The direct approach simply counts the quantity of units produced, for example, bushels of wheat or tons of steel. Such direct quantity measures are available for some manufacturing industries from Censuses of Manufactures. The reliability of these measures is likely to be greatest in industries with homogeneous (undifferentiated) products. These are also the industries to which the "law of one price" (purchasing power parity) should apply most strongly and in which international equalization of productivity is therefore most likely to occur.

The accounting identity $Q = V/P$, where V = nominal output and P = output price (or output deflator) underlies the second, indirect, approach to real output measurement. Generally, the measurement of V is subject to minimal error, so Q can be measured (and compared) accurately if reliable price deflators are available. As the authors point out, the International Comparisons Project, conducted under the direction of Kravis, Heston, Lipsey, and Summers, has been based on this "specification pricing" approach: comparisons of the prices in different countries of goods with rather detailed characteristics, for example, a 21-inch, cable-ready, remote-controlled, color television set.

Pursuing the direct approach and comparing its results to those of the indirect approach is certainly useful. But the direct approach has some important disadvantages. As the authors note, "many products cannot be matched because they represent different qualities in terms of product mix or content." Consequently, 75 to 80 percent of output could not be covered by their procedure. Their analysis presumably does not cover most R&D-intensive industries such as aircraft, consumer electronics, and semiconductors, where the issue of international productivity leadership is perhaps of greatest concern. Moreover, previous research based on simultaneous analysis of the two approaches suggests that the specification pricing method is greatly superior. Both the U.S. Interagency Task Force for the Measurement of Real Output and Lichtenberg and Griliches[1] concluded that producer price indexes (PPIs) were far more reliable measures of output prices than census unit values (a unit value is the ratio of nominal output to the direct quantity

1. Lichtenberg and Griliches (1989).

measure). The latter estimated that the signal-to-noise ratio of the PPI was more than five times higher than that of the unit value.

Another, less serious limitation of the paper's approach is that the authors constructed ''benchmark'' estimates of relative productivity levels for only a single year—1987; ''the time series for real output and labor input in total manufacturing and for the major branches from 1950 to 1990 were linked to the benchmark estimates of relative productivity levels for 1987 to obtain trends of comparative productivity.'' In principle it would be desirable to obtain benchmark estimates for at least one other year, although the effort required to do this is apparently considerable.

Despite these concerns about various aspects of the authors' methodology, I believe that their major findings are basically correct. A partial summary of these findings is as follows: All countries exhibited catch-up on the U.S. manufacturing productivity level up to the early 1980s. In 1990, however, only the United Kingdom and Japan showed significantly higher productivity levels relative to the United States than they had in 1979. The overall U.S. leadership position in manufacturing has strengthened during the 1980s, although its leadership position has been much more secure in light industries than in heavy and investment industries. Moreover, during the 1980s catch-up and convergence appeared to continue *outside* of manufacturing.

Much of the remainder of the paper attempts to explain changes in international relative productivity levels in terms of capital intensity, labor quality, and other factors. To assess the role of capital intensity, the authors developed their own capital stock estimates through the perpetual inventory method, using ''standardized'' assumptions on asset lives and the retirement of assets, which is commendable. They found that German and Japanese capital intensity converged toward U.S. levels throughout 1950–90 (except for Germany in the 1980s) and that as a result, labor productivity converged more rapidly on the U.S. level than did joint factor productivity.

The authors considered the role of investment in equipment and structures but not of investment in research and development. I believe this would have been appropriate even though (as noted above) their sample probably excludes most high-technology industries and although the uncertainty about the magnitude of the (social) rate of return to

Table 1. Nondefense R&D Expenditure by Year and Percentage Increase
Billions of constant U.S. dollars

Year	*Germany*	*Japan*	*United States*
1971	10.1	13.2	41.8
1979	14.2	21.1	52.4
1988	19.9	42.0	78.4
		Percentage increase	
1971–79	40.6	59.8	25.4
1979–88	40.1	99.1	49.6

Source: National Science Board. 1991. *Science and Engineering Indicaters—1991*. NSB91-1. Washington, D.C.: Government Printing Office.

research and development (R&D) is greater than the uncertainty about the return to fixed investment. Many studies at the firm, industry, and aggregate levels provide strong support for the hypothesis that private R&D has a strong positive effect on productivity. Moreover, relative R&D spending patterns in these three countries in the 1970s and 1980s are consistent with the relative productivity levels (table 1): during the 1970s nondefense R&D spending grew least in the United States; in the 1980s, it grew least in Germany.

With regard to labor quality van Ark and Pilat considered the effects on productivity levels in 1987 (but not on growth rates) of differences in the distribution of workers by educational qualifications. They reduced education-related wage differentials ‘‘by 40 percent to exclude the effect of other factors . . . such as ability or social background.’’ This adjustment is rather ad hoc. Also, although reducing the wage differential in this way may be appropriate for determining the rate of return to education, I do not think that it is appropriate for quality-adjusting labor input.

The authors might have considered disaggregating labor input by other attributes potentially correlated with productivity, especially age. Adjusting for age might be very important in light of the very different experiences those three countries have had in terms of the size and age structures of their populations and labor forces. Between 1965 and 1987 the percentage increases in the labor forces of these countries were: Germany, 4 percent; Japan, 27 percent; and the United States, 61 percent.

Table 2. Median Age of Population of Germany, Japan, and the United States, 1950–90

Year	*Germany*	*Japan*	*United States*
1950	34.6	22.3	30.2
1960	34.4	25.5	29.4
1970	34.3	29.0	27.9
1980	36.7	32.6	30.0
1990	38.5	36.8	32.8
		Percentage increase	
1950–80	6.1	46.2	−0.1
1980–90	4.9	12.9	9.3

Source: United Nations. 1986. *World Population Prospects: Estimates and Projections as Assessed in 1984.* Population Studies 98. New York.

Table 2 presents data on the median age of the populations of these countries from 1950 to 1990. (It would be preferable to have data on the age distribution of manufacturing workers.) Again, the pre- and post-1980 changes in median age "fit" the changes in relative productivity. The United States is the only country whose median age declined between 1950 and 1980 (due to the "baby boom"). This may have reduced its relative productivity: the age-earnings profile is positively sloped (at least up until age fifty-five or so), although this does not necessarily arise from a positively sloped age-productivity profile. In the 1980s the median age of Americans increased more than that of Germans.

After "correcting" for capital intensity and labor quality, the authors make further adjustments for the effects of industrial structure and firm size. They argue that "a concentration in activities with a low absolute level of value added per hour worked may help explain a relative low productivity level for manufacturing as a whole in one country compared with another." Of course, if factors were mobile, we would expect productivity to be equalized across sectors. The authors do not "explain their explanation": why don't labor and capital move from low- to high-productivity activities?

I have the same reservation about their adjustment for firm size. The authors argue that "labor productivity gaps between countries are to some extent related to differences in firm size" because "plants with few employees show lower value added per person employed than large

Table 3. Output and Investment per Employee and Total Factor Productivity, by Establishment Sizes

Size	*VA*	*INV*	*N*	*EMP*	*Y/L*	*I/L*	*TFP*
1–249	316,308	25,430	335,318	8,355	37.9	3.04	27.1
≥ 250	507,811	49,161	13,067	9,463	53.7	5.20	32.7

Source: Author's calculations, based on Bureau of the Census, U.S. Department of Commerce. 1985. *1982 Census of Manufactures* MC82-S-1 (Part 2) Subject Series, General Summary, Industry Statistics by Employment Size of Establishment. December.

Notes: Size = number of employees.
VA = value added, in millions of dollars.
INV = capital expenditures, in millions of dollars.
N = number of establishments.
EMP = total number of employees, in thousands.
Y/L = VA/EMP.
I/L = INV/EMP.
TFP = $(Y/L)/[(I/L)^{0.3}]$.

plants,'' and countries have different distributions of plant size. Why don't resources flow from small to large firms? Actually, it is the size of the establishment (or ''local unit''), rather than the size of the firm, that the authors adjust for. They argue that ''the local unit is the most relevant concept for an analysis of the impact of average size on productivity.''[2] This is not necessarily the case; I have found that the total factor productivity of a plant is positively related to the size of the parent firm (measured by the number of plants owned by the parent).[3]

Even if adjustment for each of the productivity determinants considered by the authors—capital intensity, labor quality, industrial structure, and firm size—is appropriate, those adjustments should be made simultaneously rather than sequentially, because the adjustments are not generally independent. Sequential adjustment poses the risk of under- or (more likely) over-adjustment, when the adjustments are correlated. Table 3, based on U.S. *Census of Manufactures* data, indicates that investment (and capital stock) per worker are higher in large establishments: capital intensity and firm size are positively correlated. The authors' separate adjustments for the two effects probably overadjust.

General Discussion: Methodological and measurement issues dominated the discussion. Several participants argued the merits of the authors' choosing to use unit value ratios in currency conversion rather

2. The definition of median establishment size is somewhat peculiar. Apparently what this means is the size of the establishment in which the median employee (ranked by establishment size) is employed. The median establishment size (about ten) is smaller than the mean (about fifty).

3. Lichtenberg (1992a).

than purchasing power parities. Robert Gordon said that unit values yield poor results because they are completely contaminated by changes in the product mix. He stressed that he had been able to use them in his own work for only two homogeneous programs where additional information on unit sizes had been available. Eric Bartlesman, however, argued that the authors had chosen correctly because unit value ratios allowed them to collect both price and quantity data from the same source. By contrast, he said, the Bureau of Labor Statistics has been creating industry-based producer price indexes from inconsistent data sources, without knowing what prices to collect and for which products. Steven Davis contended that the reliability of unit value ratios could be confirmed if it were shown that they helped to explain cross-industry patterns of trade flows.

Zvi Griliches suggested that the authors use an indicator other than median age to measure age effects on productivity because that indicator is highly insensitive to the changes in the age structure occurring in the labor forces of these countries. Ernst Berndt noted that the paper reports much lower labor factor shares for Japan than for Germany and the United States. He surmised that this is an error, attributable to the exclusion of year-end bonuses from the Japanese data on labor income; these bonuses represent a substantial portion of total labor compensation in Japan. Berndt said that correcting the data should bring Japanese labor factor shares up to the level of the other two countries. Wondering why some of the variables explain productivity gaps at the industry level but not at the level of manufacturing as a whole, Ishaq Nadiri said that the authors need to explore this phenomenon more closely.

Michelle White noted that workers in European countries generally have longer vacations, shorter work weeks, more generous disability leaves, and lower retirement ages than workers in the United States. Because these factors would seem to give Europe a healthier, fresher labor force than the United States has and consequently would have a positive effect on relative European productivity, she suggested controlling for them in international productivity comparisons.

John Helliwell argued that there is inadequate understanding of the international transmission of technological knowledge, which is a key factor driving productivity convergence. Noting that this transfer is not taking place through higher rates of investment in the less productive countries than in the more productive ones, as many earlier studies had suggested, Helliwell urged that more attention be paid to this issue.

Robert Gordon said that one of the most well-known and important facts presented in the paper is that the yen has appreciated almost 300 percent against the dollar in the last two decades. Because greater productivity growth and high inflation in Japan does not account for this appreciation, Gordon said, one must ask how the Japanese continue to be so competitive in their trade with the United States. This phenomenon, he said, could best be attributed to the marketing of new products, which for various reasons American consumers purchase even if the products are relatively expensive. He also suggested that quality differences, which should show up in productivity differentials, might not be accounted for properly. As an example, he argued that it would not be unreasonable to think that seemingly homogeneous products, such as Japanese-made and American-made bricks, vary in quality.

Peter Reiss said that this paper and many of the studies cited by the authors tend to assume that productivity should be converging. This assumption needs to be more closely scrutinized, he said, because it relies on a presumption of perfect factor mobility, which is clearly not present in a world of government regulations and trade barriers. Reiss also suggested that even if convergence were occurring, it might be hidden in the data by using average productivity levels for making the international comparisons. He argued that because consumption choices vary across countries, it is necessary to compare marginal productivity levels.

Robert Summers said that the paper might force changes in assumptions about the overall productivity gap between the United States and Japan. He noted a recent tendency to revise data to show that relative Japanese labor productivity is greater than previously presumed—about 80 percent of the U.S. level, rather than 70 percent. Combining the paper's results showing that Japanese manufacturing productivity is only 80 percent of the U.S. level with the commonly held presumption that Japanese service and agricultural sectors have lower relative productivity than their manufacturing sector must mean, Summers said, that overall Japanese labor productivity is somewhat lower than 80 percent of the U.S. level. His own Penn World Table (Summers-Heston) estimates for 1989 are 74 percent for output per employee and 64 percent for output per manhour.

Commenting on the authors' finding that relative German manufacturing productivity had been retrogressing over the past decade, Gordon argued that capacity in Germany is no longer enough to employ the labor force at unemployment rates of fifteen years ago. He suggested that there must be some relation between the productivity and capacity problems.

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