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PRODUCTIVITY, MACHINERY, AND SKILLS IN THE UNITED STATES AND WESTERN EUROPE: FOOD PROCESSING

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1. Introduction *

As the much-discussed US ‘productivity slowdown’ during the 1970’s recedes into the distance, several recent studies have shown that average labor productivity levels in US manufacturing and in the economy as a whole remain the highest in the world (Dollar and Wolff, 1993; O’Mahony, 1993; Van Ark and Pilat, 1993). This consensus has reawakened interest in understanding the sources of continued US productivity leadership and in particular the links between relative productivity performance and inter-country differences in the quality and utilization of physical and human capital inputs.

In this paper we address these issues by extending to the US an earlier comparison of matched samples of production establishments in the German, Dutch, French and British food processing industries. It follows a similar US-European comparison based on the precision engineering industry (Mason and Finegold, 1995). The decision to extend already-completed comparisons rather than embark upon new ones was taken in the light of the limited resources available to us. In spite of the many analytical difficulties presented by this approach, we believe the work reported here together with that in the earlier engineering paper constitutes a useful first step towards a full application of the matched-plant comparative research method to the US and thus to a better understanding of the links between capital inputs and productivity performance in different economies.

The paper is ordered as follows: in Section 2 we describe the research methodology employed and describe the samples of plants visited in each country. Section 3 provides background information the particular branch of food processing chosen for investigation, namely, the manufacture of cookies and crackers (referred to as ‘biscuits’ in Western Europe). Section 4 reports on detailed comparisons of labor productivity levels in the national samples of cookie plants. We then go on to assess the links between relative productivity performance and inter-country differences in production scale and machinery utilization (Section 5) and workforce skills and training (Section 6). We conclude in Section 7 with a brief summary of our main findings and their implications for policy-makers in the United States and other countries.

2. Methodology and sample selection

The earlier comparison of productivity performance in four European cookie manufacturing industries was based on information gathered during research visits in 1989-91 to a total of 29 factories: ten in Britain, eight in Germany, six in France and five in the Netherlands. For the US extension of this study, visits were made to eight US cookie plants during 1993-94 (see Table 1).

As described in Mason, van Ark, Wagner (1994), in this type of comparison several problems need to be overcome in drawing up samples of plants which can be usefully compared with each other and at the same time be regarded as adequately representative of each national industry. In broad terms our sampling strategy was to cover a spread of plants in the inter-quartile employment size-range in each country.[1] As shown by national Censuses of Production, the median plant size in the British industry is substantially larger than in the other three European countries. Hence, in order to obtain a substantial overlap of plant-sizes in the four European samples, additional visits were made to British plants in smaller size-groups and to German plants above the upper quartile size.[2]

In the case of the US cookie manufacturing industry, the median plant-size of approximately 520 employees is also considerably smaller than that in Britain (1200) but is above that of the three Continental European countries (see Table 2). Seven of the eight US plants visited fell within the US inter-quartile size-range; one plant below the US lower quartile size was also included to increase the overlap in terms of size between the majority of American and European plant-sizes.

In all five countries the plants visited were initially identified through trade directories. Detailed information about employment and product mix was sought by telephone before formal requests for visits were made. Response rates in the four European countries were fairly similar with approximately two thirds of plants who were formally approached for a visit agreeing to participate; in the US the response rate was about X%. During the plant visits detailed semi-structured interviews were held with senior managers (managing directors or factory managers in the case of smaller plants; production and personnel managers in larger plants). Each visit also

[1] Defined in terms of the industry's total employment (not in terms of number of plants).
[2] For purposes of data analysis the sample plants were, however, weighted in such a way that the estimates of average productivity levels remained broadly representative of the inter-quartile employment size-range in each national population. For further details of this weighting procedure, see Mason et al, 1994, Appendix A.

included direct observation of production processes and work organization on the shopfloor and it was therefore sometimes possible to speak with production supervisors and other employees as well. The visits lasted between half a day and a day and, if necessary, were followed up with further detailed inquiries by telephone or letter. In order to economize on traveling costs, the visits were geographically clustered in two or three different regions in all the countries except for the Netherlands (where distances are small).

Table 1: Distribution of plant sizes in national samples of cookie and cracker (biscuit) manufacturers.

	US	Britain	Netherlands	Germany	France
Employment size-group			*Number of plants*		
Under 200	1	2	2	3	1
200-499	2	2	2	1	3
500-999	5	2	1	2	2
1000-plus	0	4	0	2	0
TOTAL	8	10	5	8	6
			Number of employees		
Weighted median plant size in samples (a)	550	1170	280	350	380

a: The median size is here defined such that half of all employees in each sample are in plants above that size and half below it. Sample plants were weighted to ensure that subsequent estimates of average productivity levels remained broadly representative of the inter-quartile employment size-range in each national population. The unweighted sample median plant sizes were: US 580, Britain 1040, Netherlands 340, Germany 1000 and France 410.

Table 2: Medians and quartiles of population plant-size distributions in the cookie and cracker (biscuit) manufacturing industries, US, Britain, The Netherlands, Germany and France.

	US	Britain	Netherlands	Germany	France
Lower quartile	220	700	na	120	50

Median	470	1200	150-200	300	330 (c)
Upper quartile	960	1700 (c)	na	770	850 (c)

a: Refers to Cookies and Crackers (SIC 2052) in the US; Biscuits and Crispbread (Activity Heading 4197) in Britain; Dauerbackwaren (Nummer der Systematik 284.7) in Germany; Biscuiterie, Biscotterie (Economic Activity No. 3902) in France; Biscuits, Wafels, Koekjes and Banket (cake) (SBI 20.83-84) in the Netherlands.
b: Refers to local units in which cookies are the principal product of manufacture. Small production units doubling as retail premises are excluded. For France the estimated size distribution of local units in cookie manufacturing is derived from ratios of establishment to enterprise sizes in the wider food industry.
c: Median or quartile plant-sizes fell within upper size-bands for which no upper limits were specified; estimates derived by logarithmic extrapolation from smaller size bands. Sources: US: Census of Manufactures, 1992; Britain: BSO, Size Analyses of UK Businesses, 1989. Netherlands: CBS, Produktiestatistieken, 1989 and trade estimates. Germany: Statistisches Bundesamt, Unternehmen und Arbeitsstatten, Fachserie 2, Heft 3, 1987. France: SCEES, Enquete Annuelle d'Entreprise, 1988.

3. Industrial structure and foreign trade

Total employment in the US cookie and cracker industry in the early 1990's was approximately 50,000, roughly twice as large as in Britain, the biggest of the four European industries. The US industry is dominated by a handful of large multi-plant enterprises which co-exist with several dozen small, specialist (often family-run) firms. Following the restructuring of production and its consolidation in fewer, larger plants which has taken place in recent decades, the present composition of the US industry is closer to that in Britain than in any of the Continental European industries.[3] However, as noted above, the median plant-size in the US industry is still less than half that in Britain (see Table 2). Although large enterprises -- some of them multi-nationals -- account for a majority share of output and sales throughout Europe, as in the US, family-owned firms continue to play a more important role in Continental Europe (and especially in Germany) than in either the US or Britain.

While current employment levels in the US industry are much the same as in the early 1980s some European industries have seen sharp contractions in employment over the same period. Continued restructuring and rationalization of the British industry contributed to a fall of some 37% in total employment between 1980-92 and in France the reduction was of the order of

[3] For detailed background information on these inter-country differences in industrial structure, see Prais, 1981, Ch. 11.

18%. However, rapid export growth in the German and Dutch industries helped restrict their employment losses to only about 4% between 1980-92. [4]

In marked contrast to the European industries, and particularly those in Germany and the Netherlands, the role of foreign trade in US cookie and cracker manufacturing is negligible (see Table 3). As American consumer tastes have altered in recent years – for example, in favor of fat-free products – established domestic enterprises have moved speedily to meet the demand without facing serious competition from imports.

Table 3: Export and import shares in the cookie and cracker manufacturing industries, US, Britain, The Netherlands, Germany and France, 1990-92.

	US	Britain	Netherlands	Germany	France
Exports/production	1	14	43	38	15
Imports/consumption	2	6	22	29	27

Note: 1992 value shares for US, 1990 volume shares for European countries.
Sources: US: Department of Commerce, US Industrial Outlook 1994; Europe: International Office of Cocoa, Chocolate and Confectionery (IOCCC), Statistical Bulletin, Brussels, 1991.

4. Comparisons of labor productivity levels

Estimates of average productivity levels in the five cookie and cracker industries (based on national Production Census data) point to continuing US leadership over the European industries: in 1992 crude output (tonnage) per person-hour in Germany, for instance, was an estimated 40% of that in the US and even in the leading European industry (in the Netherlands), average productivity was some 30% lower than in the US (Table 4, Row 2).

This pattern of productivity advantage was largely confirmed by our own sample-based estimates of output per person-hour in each national industry. In the course of plant visits in the respective countries, detailed information was gathered on cookie and cracker output and

[4] Sources for employment data: US, Annual Surveys of Manufactures, various issues; Britain: CSO, Report on the Census of Production and Size Analyses of UK Businesses, various issues. Netherlands: Employment: CBS, Produktiestatistieken, various issues and Produktschap voor Granen, Zaden en Peulvruchten. Germany: SB, Produzierendes Gewerbe: Kostenstruktur der Unternehmen and Statistisches Jahrbuch, various issues. France: INSEE, Annuaire Statistique and Ministère de l'Agriculture et de la Foret, Agreste: La Statistique Agricole.

associated employment -- both direct and indirect -- over a recent 12 month period (a sufficient length of time for our calculations not to be distorted by seasonal fluctuations). In all cases we confined our attention to the production of a strictly-defined category of cookies and crackers (‘biscuits’ in the European sense) including, for instance, plain, sweet, semi-sweet, savory and chocolate-coated products but excluding related products such as wafers, waffles, rusks as well as any cake or confectionery goods. Wherever cookies or crackers were not the sole item of manufacture, guidance was sought from production managers as to how the indirect labor input should be allocated between cookies/crackers and other products.

Table 4: Estimates of productivity levels in cookie and cracker manufacturing
Index numbers: US = 100, rounded to nearest five.

	US	BRITAIN	NETHERLANDS	GERMANY	FRANCE
			Output (tons) per person-hour		
Samples of plants, 1993 (a)	100	70	80	55	70
National production censuses, 1992 (b)	100	55	70	40	65

Notes:

a: Relates to comparable narrowly-defined ranges of cookies and associated labor inputs.
b: Wider coverage of products, varying from country to country, and including some employees involved with non-cookie products. The census product definitions in each country are as follows:
US (Cookies and crackers): Crackers, pretzels, biscuits and related products; cookies, wafers and ice cream cones and cups.
Britain (Biscuits and crispbread): Rusks, crispbreads and matzos; savoury biscuits; chocolate covered biscuits; sweetened biscuits; semi-sweetened biscuits; unsweetened biscuits - plain.
Germany (Dauerbackwaren): Zwieback; Leb- und Honigkuchen, Printen; Hart- und Weichkeks; Waffeln; Gefüllte Riegel; Salz- Käse- und Laugen Gebäck; sonstige Dauerbackwaren.
Netherlands: Biscuits, wafels e.d.; Koekjes, banket e.d.
France (Biscuiterie-biscotterie): Biscuits salés; biscuits secs; gaufres et gaufrettes; biscuits patissiers; autres biscuits divers; patisseries de conservation; pains d'épices; biscotterie.
c: European sample-based estimates for 1993 based on extrapolations (using indices of production and employment in each country) of earlier estimates made for 1989-91. European census-based estimates for 1992 are based on similar extrapolations of 'benchmark' estimates for 1990.

Sources for Census-based estimates:
Employment and annual total sales value of cookies produced: US Department of Commerce, Census of Manufactures; CSO, Report on the Census of Production; SB, Produzierendes Gewerbe: Kostenstruktur der Unternehmen; CBS, Produktiestatistieken; INSEE, Annuaire de Statistique Industrielle.
Average ex-factory sales value per ton of cookies: US Department of Commerce, Census of Manufactures; CSO, Quarterly Sales Enquiry; SB, Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten; CBS, Produktiestatistieken; INSEE, Enquete Annuelle d'Entreprise (SCEES).
Annual hours worked per employee: based on estimates for food and drink industries in each country in B. van Ark, International Comparisons of Output and Productivity, University of Groningen Growth and Development Center, Monograph Series, No. 1.

Using this information, together with appropriate adjustments of the European data for estimated hourly productivity growth between 1989-93, simple measures of crude output (tonnage) per employee-hour were derived which showed average productivity levels in US sample plants to be approximately 25-40% higher than in the Dutch, French and British samples and about 80% higher than in German plants (Table 4, Row 2). [5]

[5] As Table 4 shows, our sample-based estimates for 1993 point to a generally narrower US lead in crude productivity levels than that suggested by the Production Census-based estimates for 1992. This

However, in the course of the earlier intra-European comparison, marked differences were observed in the mix of product-qualities produced by each national industry which suggested that an output measure based simply on tonnages was hardly adequate for comparisons of real productivity performance. For example, the more basic (undecorated) varieties of cookies accounted for a much larger proportion of output in the British sample than in the other European countries and this was particularly the case in relation to the German sample (which produced a relatively large share of more complex, multi-textured cookie products with elaborate packaging). As well as requiring less secondary processing and packaging, basic-quality biscuits are typically produced in large batches and are thus more amenable to automation of production than are the higher-quality grades of biscuit. When new estimates were prepared which took account of inter-country differences in value added per ton as well as differences in tons produced per employee-hour, it was found that the country rankings in respect of 'quality-adjusted' productivity levels changed sharply, with the German industry coming out ahead of the other three European countries (Mason, van Ark, Wagner, 1994).

In Appendix A we describe similar calculations which take account of differences in the mix of product-qualities between the US and European industries, with quality differences defined in terms of physical characteristics such as the number of processes involved in the production of different types of cookie and cracker and the types of ingredient and packaging materials which are used. As Table 5 shows, when the outputs of all plants visited were allocated to four different grades of product, the US industry -- in common with Britain -- was found to be heavily concentrated in the less complex basic- and medium-grade quality-brackets. Sales price data for the different grades of product were then used along with Production Census information to derive a rough index of value-added per ton in each national sample and this in turn was combined with the earlier measures of (crude) output per employee-hour in each national industry to obtain estimates of quality-adjusted productivity levels (see Table 6).

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disparity may partly reflect measurement error as well as the inherent limitations of working with relatively small samples of plants. However, it is important to note that the Production Census data cover a wider and more variable range of products for each country than do our sample-based estimates (see Table 4, Note b).

The results of this exercise suggest that the substantial US advantage in crude output (tonnage) produced per employee-hour is sufficient to maintain overall US leadership in respect of value added per employee-hour as well. However, the quality-adjusted productivity gap between the US and German industries is found to be much narrower than that suggested by comparisons based on a simple tonnage measure of output. Any assessment of the links between relative productivity performance and the quality and utilization of production inputs in this industry therefore needs to take due account of the patterns of difference shown by both types of productivity measure.

Table 5: Distribution of output (tonnage) by quality-grade in national samples of cookie and cracker manufacturers.

Percentage shares of output, rounded to nearest five

	US	BRITAIN	NETHERLANDS	GERMANY	FRANCE
Basic-single wrapping	15	35	25	15	20
Basic-multiple wrappings	30	0	0	0	0
Medium	50	60	60	50	70
High	5	5	15	35	10
TOTAL	100	100	100	100	100

Note:
The four grades of product quality are defined as follows:
1. Basic-quality, single wrapping: 'dry' undecorated cookies or crackers made from relatively cheap ingredients (e.g. vegetable or animal fats), stacked in cylinder-form and wrapped in a single layer of plastic film.
2. Basic-quality, multiple wrappings: as described for Grade 1 but with more than one layer of packaging (very commonly found in the US but rare in the European countries; see Appendix A for further discussion of this point).
3. Medium-quality: cookies requiring at least one secondary production process after baking such as chocolate-coating or sandwich-filling with cream or jam; usually sold with at least two layers of packaging. Undecorated cookies made with more expensive ingredients such as butter are also included in this category.
4. High-quality: elaborate, multi-textured cookies requiring two or more secondary (post-baking) production processes, usually stacked in successive small piles, multi-wrapped and boxed; includes assortments of cookies made from expensive ingredients.

Table 6: 'Quality-adjusted' estimates of labor productivity levels in national samples of cookie and cracker manufacturers.

Index numbers: US = 100, rounded to nearest five

	US	BRITAIN	NETHERLANDS	GERMANY	FRANCE
Output (tons) per person-hour	100	70	80	55	70
Value added per ton	100	95	105	165	110
Quality-adjusted' output per person-hour	100	65	85	90	75

Notes: see Appendix A for details of calculations.

5. Production scale and machinery utilization

5.1 The production process

The present concentration of cookie output in a relatively small number of plants in all five countries reflects competitive pressures over many decades to seek ever-greater economies of scale in production (as well as in marketing and distribution). Modern cookie manufacturing now typically employs continuous-flow methods of production with primary ingredients being bulk-fed to mixing machines from where the dough passes through rolling and cookie-shaping (‘forming’) machinery before entering conveyor-fed ‘traveling’ line ovens. In the subsequent post-baking stages of production the cookies are conveyed by moving belts through secondary processing machines if required (for example, for creaming, chocolate coating or jam-filling) and then to the final stages of wrapping and packing.

In general the extent to which scale-economies can be maximized through automation of this production process depends greatly on the product strategy adopted. For example, a handful of plants visited had exceptionally long production runs of standardized cookies and their entire mixing process was run on an automated continuous basis. However, the great majority of plants visited in all five countries engaged in batch mixing on all their production lines with periodic ‘changeovers’ of dough-forming, wrapping and other equipment further down the line.

Regardless of the product mix, the wrapping process was invariably automated but there was considerable variation in the methods adopted to handle the cookies before and after they passed through the wrapping machines. In some cases collating and positioning of the cookies was carried out by hand as was the subsequent packing of the cookie packets in cartons ready for transportation to the warehouse. The labor-intensive nature of packing work reached a peak in those factories, most commonly observed in Germany but also important in France, which specialized in preparing tins of assorted cookies.

In plants where changes of product varieties and packet sizes were relatively infrequent, vibratory systems or other equipment had been installed to stack the cookies gently in lanes and feed them into automatic collating machines prior to the wrapping stage. Machinery of this kind was seen most often in the United States and Britain and to a lesser extent in the Netherlands and France, reflecting their respective output shares of basic- and medium-grade cookies. In a very few cases -- more common in the US than anywhere else -- post-wrapping activities such as cartoning and palletization had also been automated.

5.2 Production scale and productivity

In order to explore the effects of production scale on relative productivity levels, we carried out some simple regression analysis which related average weekly employment in each plant to its weekly tonnage level. As shown in the first column of Table 7, the results suggest that, across all five samples of plants, and without taking any account of differences in the mix of product-qualities, a doubling of weekly output (y) is associated with an increase of only 71.7% in weekly labor input (n) and hence with an increase in labor productivity (y/n) of approximately 16% -- confirming the importance of scale-economies in this industry. A second regression (7.2) with controls for product quality points to a smaller increase (7%) in labor productivity associated with a doubling of weekly output, reflecting the close links between product quality and the labor-intensity of production at plant level.[6]

In further regressions we included dummy variables designed to capture the average productivity differentials between plants located in the US and the other four countries while controlling for production scale. As shown in Column 7.3, the results suggest that, at a given level of weekly tonnage per plant, labor productivity (tons per employee-hour) in US plants falls below

[6] In summary, the results of regression 7.2 suggest that, at comparable levels of output, basic-quality cookies need only 35% of the average labor input required by high-quality cookies while medium-grade cookies need an average 62% of the labor input associated with high-quality products. Note that these results are necessarily based on a crude classification of plants to a

that in the Netherlands but is on average just over 40% above that in British plants and is also still higher than French and German productivity levels. However, only the estimated differential between US and British plants is statistically significant at the 5% level. Similar results are obtained when quality-grade dummies are included as well (7.4); while the US productivity lead over Britain remains large and statistically robust, it is not possible to identify statistically significant productivity differences between US and Continental European plants.

single quality-bracket (representing 50% or more of total output) whereas, in fact, the output of many plants comprises a mix of two different product grades.

Table 7: Regressions of weekly labor inputs on weekly output of individual cookie plants.

Dependent variable: ln n (total employee-hours per week)

	(1)		(2)		(3)		(4)	
Constant	1.13	(2.66)	0.94	(2.81)	1.05	(2.30)	0.97	(2.69)
ln y (total output (tonnage) per week)	0.78	(10.45)	0.90	(13.62)	0.75	(10.27)	0.87	(13.00)
Quality-grade dummies:								
Basic-quality			-1.04	(-4.92)			-1.01	(-4.47)
Medium-quality			-0.48	(-2.57)			-0.44	(-2.25)
Country dummies:								
Netherlands					-0.19	(-0.64)	-0.06	(-0.24)
Germany					0.28	(1.11)	0.12	(0.58)
France					0.33	(1.18)	-0.02	(-0.09)
United Kingdom					0.53	(2.14)	0.42	(2.16)
Adjusted R square	0.75		0.84		0.77		0.86	
SEE	0.55		0.43		0.52		0.41	
No. of observations	38		38		38		38	

Notes: T-statistics in parentheses.
Quality-grade dummy variables set to zero in the case of plants with 50% or more of output classified to high-quality grade. Country dummies set to zero in the case of plants located in the United States.

In summary, we may conclude that the actual US productivity lead in this industry -- in terms of both tonnage-based and quality-adjusted measures of output per employee-hour -- derives in large part from its greater scope for technical economies of scale. This conclusion is actually reinforced by further consideration of the US lead over Britain which was found to exist even at similar levels of total output. Although the proportion of British sample output devoted to high-volume production of standardized varieties of cookies is very similar to that in the US, production runs are typically even longer in American plants than in their British counterparts. Data on the 'average' length of production runs are hard to obtain but one indication of American-British differences in this respect is given by the following example: some 56% of US sample output was produced in plants which 'usually' ran some production lines uninterrupted (without product and machinery changeovers) for five days or longer; in the British sample only 28% of total sample output was produced in plants of this kind.

The overall US advantage in length of production runs primarily reflects the relatively large size of its domestic market. Although some American sample plants had individual oven-lines producing for nationwide distribution, the majority were mainly geared to serving regional markets. However, most of these regional producers were still able to operate at volumes achieved only by the very largest British plants which are geared to the UK national market for certain kinds of standardized product. In the case of German, Dutch and (to a lesser extent) French plants, their effective market size is increased by their greater propensity to export but, even when producing relatively standardized varieties, their longest single production runs rarely extend beyond 24 hours (and in most cases would be shorter).

Longer production runs in many US plants not only help to minimize the time lost due to machinery changeovers but also, as described in Section 5.1, facilitate more widespread use of both dedicated machinery and automated equipment than in any of the European countries. This applies even to the production of medium-quality cookies involving several different post-baking production processes. We now turn to a more detailed examination of inter-country differences in the quality and utilization of physical capital equipment.

5.3 Age and capacity of machinery

In general terms, the age of cookie-making equipment can be taken as a fair indicator of its level of technical sophistication. For instance, each new generation of ingredient handling systems permits faster and better controlled distribution of ingredients to mixing machines. New ovens tend to require shorter start-up times at the beginning of each day and to respond more quickly to adjustments made by operators; this greater accuracy in control reduces product wastage and permits faster changeovers between product varieties. In the area of wrapping machinery technical advances continue to improve performance in terms of speed, reliability and ability to undertake complex operations.

As shown in Table 8, the average age of ingredient handling, mixing and baking machinery in US plants was broadly comparable to that in the British, German and French samples. In this respect the main outlier was the Dutch industry where such equipment averaged just under 20 years in age, as compared with 12-16 years in the other four countries. In the case of wrapping and packing machinery, all five samples of plants had renewed much of their equipment in the last ten years, reflecting both the heavy wear and tear to which such machinery is subjected and the need to keep up with the rapid pace of technical change. It seems apparent, therefore, that US productivity leadership in this industry can hardly be attributed to any advantage in the newness and sophistication of its capital equipment.

Table 8: Estimated average age of machinery in national samples of cookie manufacturers. (a)

	US (b)	BRITAIN	NETHERLANDS	GERMANY	FRANCE
			Age in years		
Preparation and mixing equipment	14	12	19	14	15
Ovens	13	16	19	13	14
Wrapping equipment	9	9	10	7	7

Notes:
a: Calculations based on detailed age-distributions in Appendix Table B1: mid-points taken for two closed intervals; top (open) interval assumed to have mid-point of 15 years in the case of wrapping equipment and 20 years in the case of preparation and mixing equipment and ovens.
b: The US age-distribution shown here is estimated for 1990-91 to ensure comparability with European data collected during that period. However, estimates for 1993-94, shown in Appendix Table B1, suggest that the age-distribution of machinery in US plants has not altered greatly since the early 1990's.

However, other characteristics of the physical capital in use in US sample plants can be directly linked to relative productivity performance. As noted above, American plants tended to make greater use of automated equipment in post-baking areas of the production process such as cartoning and palletization, and were also more likely to 'double up' on wrapping machinery so that the output from given oven-lines could be switched from one dedicated (or semi-dedicated) set of wrapping equipment to another with little time needed for the changeover. In addition, there were marked US-European differences in the physical capacity of equipment at earlier stages of the process. In particular, US plants were typically operating with larger mixing machines than those found in Europe and with wider and longer conveyor-fed ovens, thus permitting a faster throughput of product. For example, in the four largest US sample plants (defined in terms of average tonnage per week), some 80% of oven chambers were 75 meters or more in length as compared with only 35% of oven chambers in the four largest British plants. In the earlier intra-European comparison, inter-country differences in machine capacity tended to reflect differences in the age-distributions of equipment but this relationship does not hold in US-European comparisons. Over the decades the larger domestic market served by US producers has clearly enabled them to install higher-volume versions of the same vintages of equipment found in Europe.

5.4 Machinery utilization and maintenance

The five largest of the eight US plants typically worked all or most of their oven-lines for 24 hours per day, five days per week, with some weekend overtime during periods of peak demand. This intensive use of machinery was second only to the British sample where eight of the ten plants visited were operating in much the same way. In France half the plants had 24-hour operations and half had two shifts per day. In Germany most plants operated only two shifts per day, in part because of legal restrictions on the employment of women (packing workers) during night shifts In the Netherlands spare capacity at the time of our visits limited production to a single shift per day in the majority of plants (with some evening work in the high season).

These inter-country differences in machine utilization affected relative labor productivity performance in several ways.[7] As noted above, in cookie plants where the majority of oven-lines were dedicated to single products -- with few changes in packet sizes -- there were clear benefits in the long production runs permitted by continuous multi-shift working, and the US sample was best-placed to take advantage of this. However, in European plants the more varied product mix dictated frequent changeovers of machinery and hence productivity performance depended heavily on the ability to schedule major changeovers for times when production lines were not fully manned (e.g. overnight). In general, the German and Dutch plants making less intensive use of equipment were better placed to optimize their scheduling in this way. By contrast, many British plants working three full shifts per day were also under considerable pressure to respond quickly

[7] A fuller assessment of inter-country differences in machinery utilisation would need to take account of output fluctuations over the course of recent business cycles in each country. This could not be attempted within the scope of the present study.

to diverse and rapidly-changing customer requirements; hence, they were much less able to avoid inefficient use of labor while machinery changeovers were being made.

Relative productivity levels were also affected by different rates of machine breakdown and malfunctioning which, in a continuous-flow production process, have serious consequences in terms of product wastage and the additional labor required to sort out problems. During our plant visits we observed some examples in all five countries of production lines which had been halted in mid-production or were not working smoothly. However, the incidence of equipment failure was highest in the British sample with the most common problems arising from hard-worked conveyor belts and wrapping and carton-sealing machines and, in some cases, from long-standing difficulties in getting complex new ingredient handling and mixing systems to perform to requirements. US plants making similarly intensive use of machinery were also visibly experiencing more problems with production flow than Continental European plants but this often took the form of sustained malfunctioning (for example, with a proportion of output being lost through spillages on the floor) rather than outright stoppages of production lines.

This distinction between equipment failure and malfunctioning needs to be borne in mind in comparisons of 'emergency downtime' rates in the five countries. In spite of the relatively high incidence of faulty equipment in the American sample, US plants reported an average of just under 4% of planned machine-working time actually lost due to breakdowns and other unexpected stoppages, much the same as average downtime in Germany, France and the Netherlands and substantially below the average 10% emergency downtime rate reported by British plants. Discussions with American production managers suggested that one reason for their relatively low average downtime rates was their willingness to tolerate equipment malfunctioning -- and associated product wastage -- in order to meet inflexible corporate production targets and to secure the overall cost advantages of long, uninterrupted production runs. While managers were clearly anxious to reduce wastage rates -- which in one US plant reached as high as 10-11% -- it was deemed 'cost-effective' to accept such losses in the short-term rather than shut down production lines for adjustments or repairs during planned working-time. In the words of one American manager, he and his colleagues had in the past been 'too focused on minimizing waste' and they had tended to shut lines down 'too early and too often' whenever there were problems.

At the same time lower recorded downtime in US plants was also associated with preventative maintenance practices which were closer to those in Continental Europe than in

Britain. As many as four-fifths of the Dutch and German plants had implemented full planned maintenance programs as had two-thirds of the French plants. While only three of the eight American plants undertook regular preventative maintenance, another four US plants reported taking every opportunity to carry out such maintenance whenever production schedules permitted equipment to be idle for long enough (for example, at weekends). By contrast, only a fifth of the British plants visited reported serious efforts to carry out routine maintenance and a majority of them appeared to be trapped in a vicious circle with high levels of emergency maintenance militating against the introduction of preventative maintenance procedures which might help reduce the incidence of breakdowns.

In some cases the relative lack of planned maintenance in British plants was also attributed to pressure for intensive machine-working in order to ensure a rapid 'payback' on new investments. However, reported payback times in US plants (usually 1 to 2 years) were much the same as in Britain. Our discussions with both British and American managers suggested that the greater efforts by the latter to undertake preventative maintenance simply reflected the over-riding importance to their high-volume product strategy of minimizing outright stoppages of production lines. No such clear-cut strategy was available to the majority of British plants who were typically dealing with a much more varied mix of customer orders, dictating more changeovers of machinery, than their American counterparts.[8] Such differences between national industries in predominant product strategies also had significant implications for the quality and utilization of human capital assets which we now go on to explore.

6. Production organization and workforce skills

6.1 Vocational qualifications and training

In all five samples of plants direct labor accounted for between 70-80% of total employment with the great majority of shopfloor workers employed in post-baking (secondary processing, wrapping and packing) areas of production. Wrapping and packing work was carried

[8] In all but two British plants production managers reported regular daily pressures to respond quickly to rapidly-changing customer requirements with even fairly similar products having different specifications in terms of ingredients, dimensions, packaging and so on.

out everywhere by a largely unqualified workforce. The main differences in workforce skill levels occurred in the more technically demanding occupational areas -- shopfloor process departments, maintenance engineering and technical support activities such as production planning, project engineering and product quality assurance.

Broadly speaking, the pattern of formal qualifications in each sample of plants reflected the institutional structure of vocational education and training provision in each country. Thus in the US sample, as will be described below, there were relatively large numbers of employees with four-year college degree qualifications in technical support areas but much fewer persons with formal 'intermediate' (craft- and technician-level) qualifications. By contrast, a significant proportion of employees in the German sample had passed through the well-known 'Dual System' which combines employment-based apprentice training with obligatory part-time attendance at vocational schools. In the Dutch and French plants most vocational qualifications had been acquired in the course of full-time vocational schooling which for many employees had begun in the latter stages of compulsory education. In addition, the Dutch sample had relatively high proportions of employees in key occupations with technician-level qualifications, reflecting the widespread provision of full-time vocational education at age 16-plus in the Netherlands. In the British case there was a mix of qualifications gained through employment-based apprenticeships and full-time vocational courses but the proportions of employees with either type of qualification were relatively low by Continental European standards and were only slightly above US qualification levels.

As a consequence of increasing competitive pressures (partly reflecting the concentrated buying power of large supermarket chains in each country) and the need to keep up with new technological developments, the majority of plants visited in all five countries had recently increased their expenditure on both initial and continuing training for certain groups of employees. However, with the possible exception of France -- where spending on adult training is encouraged by specific legislation -- the nature and volume of such training hardly began to bridge the inter-country skill gaps indicated by differences in formal qualification levels.[9] These disparities in

[9] See Mason et al, 1994, Section 5.7 for detailed examples of continuing training initiatives which were most commonly, or only, found in French plants.

turn were closely linked to differences in the quality-mix of output and to the relative efficiency with which different product strategies were implemented in each national industry.

6.2 Production process skills and product strategy

The employees involved in the ingredient handling, dough-mixing, forming and baking stages of cookie production are defined here as 'process workers': they include mixermen/women (and/or computer operators in a mixing control room), machine operators and ovensmen/women.

Process work in cookie manufacturing largely centers around the achievement and maintenance of detailed product specifications in the face of considerable variability in raw material qualities (texture, moisture and so on) and differences in weather conditions (affecting ambient temperatures). In the course of production, variables such as the temperature and consistency of the dough mix and the diameter, thickness, weight, shape, moisture content and color of the cookies need to be repeatedly monitored. As conditions change from day to day (or batch to batch) it may be necessary to make a series of alterations to the dough-mixes initially specified by standard recipes and to adjust forming machine-settings, conveyor belt speeds and oven temperatures (Manley, 1991).

In general, the skills and knowledge required for this work rise sharply as the number and complexity of products made is increased. At the same time small batch sizes and the use of expensive ingredients reduce the scope for protracted 'trial runs' with individual varieties before full production begins. Hence plants specializing in small- and medium-batch production of high-quality multi-textured cookies are likely to depend greatly on the know-how and experience of skilled bakers in their process departments.

In the German sample which, as noted above, was heavily concentrated in high-quality product areas, some 90% of process workers were indeed craft-trained bakers who had been recruited on the open market, a procedure facilitated by a surplus of apprentices in the craft-baking industry. In addition three quarters of German production supervisors had undertaken further training to *Meister* standard in a range of technical and management areas which had equipped them well to liase with support services such as maintenance and (as discussed further below) to advise on incremental improvements to production processes.

By contrast, in the American and British plants visited there were no process workers and very few supervisors with vocational qualifications. The designation of process work as 'semi-skilled' in both these countries reflected the primary orientation of their cookie industries towards longer runs of relatively simple product types. In this type of production the need for judgment and skill on the part of process workers is much reduced. This is particularly the case in factories where manual monitoring and adjustment activity has been supplemented or replaced by computerized control systems, although even in these circumstances there is a recurrent need for some manual intervention to maintain a consistent product and wastage may occur if operators do not fully understand the consequences of their actions or inaction (Buchanan and Boddy, 1983, Ch. 11).

In relation to these German and US/British extremes of product strategy and process skill requirements, the Dutch and French samples both occupied intermediate positions. As outlined in Section 4 above, the average value added per ton of output in the Netherlands and France was higher than in the US or Britain but was still substantially below the average level of value added in Germany. Both the Dutch and French samples had significant proportions of vocationally-qualified process workers and supervisors but few of them were apprentice-trained bakers as in Germany; this deficiency had been partially offset by longer average periods of on-the-job training than occurred in Germany.

Table 9: Qualifications and training of production process workers and supervisors in cookie plant samples.

US	**BRITAIN**	**NETHERLANDS**	**GERMANY**	**FRANCE**
Process workers				
No vocational qualifications	No vocational qualifications	40% qualified at junior vocational schools	90% craft-skilled bakers	10% craft-skilled bakers
Initial on-the-job training:				
Average 2 months Usually single task area	Average 2 months Usually single task area	Average 7 months Full range of tasks	Average 4 months Full range of tasks (but not always all products)	Average 12 months Usually full range of tasks (but not always all products)

Production supervisors

Approx. 10-15% with vocational qualifications (mainly 4-year graduates)	15% with vocational qualifications (mainly university graduates)	Two-thirds with vocational qualifications	All craft-skilled bakers (almost 75% *Meister*-qualified)	40% with vocational qualifications

Indeed, further consideration of the deployment and training of process workers reveals many similarities between the three Continental European industries as compared to the US and Britain. For example, in German, Dutch and French plants initial on-the-job training for process workers was designed to equip them to switch flexibly as required between all main areas of operation (mixing, cookie-forming and oven control). In the German plants this training averaged only four months in length, reflecting the prior experience of trainees in the craft-baking sector. In the Netherlands newly-recruited process workers received on average seven months initial training and in France approximately 12 months.[10] In all three Continental European industries the great majority of plants were able to operate with three-person teams of process workers taking responsibility for the mixing and baking stages of production on at least two oven-lines at a time.

In the US and British samples average initial on-the-job training times for process workers were much shorter (averaging only two months in each case) and typically covered only a single task area (e.g. mixing). At later stages of their careers American and British process workers could receive further training for other jobs (e.g. oven-operator) but -- in contrast to their counterparts in Continental Europe -- they were rarely expected to take responsibility for more than one task area at a time. As a result, in the American and British plants visited, each individual oven-line usually needed its own three-person team of process workers even when the cookies being made were ostensibly simple and undemanding in nature. In some cases this reflected the sheer length and width of some oven-lines which made it physically unrealistic for workers to work on more than one line at a time. However, the short and narrow training received by process workers in both the US and Britain also clearly limited their ability to deal with problems that might arise simultaneously on different oven-lines. Indeed, one American manager

[10] Note that these simple comparisons of initial training times are unable to distinguish between 'instruction periods' of training (when trainees contribute little or nothing to output) and periods of 'learning by experience' (when some productive contribution is made). Further information supplied by French plants suggested that their reported initial training times for process workers included relatively long periods of 'learning by experience' in each task area before moving on to a period of instruction in another.

even voiced doubts about his employees' ability to carry out routine tasks such as quality checks if they were given responsibilities outside a narrowly-defined task area on a single line.

In both the American and British samples we encountered a few isolated examples of current or past experimentation with functional flexibility among process workers (with associated extra investments in training). Following the recent spread of systematic 'quality management' practices in manufacturing, some managers could see such flexibility as a means of developing employees' knowledge about the effects of their actions on quality and efficiency at later stages of the production process. In some unionized plants in both the US and Britain the non-existence or limited nature of more flexible work patterns was attributed by managers in part to restrictive agreements on manning levels on which slow negotiations were in progress. Nonetheless, few managers in either country could imagine how they would employ skilled bakers even if they were available and several of them expressed strong opposition to excessive 'tampering' by shopfloor employees. In general, work organization in both industries still appeared to be driven in the main by past managerial commitments to removing the 'craft' element from cookie production and attempts to develop it as a scientifically controllable process with strictly defined limits on manual intervention by individual workers.

As outlined in Section 4 above, estimates of average quality-adjusted levels of labor productivity in the five industries point to continued US leadership on this basis but relegate Britain to last place. This finding is consistent with a proposition that the relatively low shopfloor skill levels (and associated patterns of work organization) which the American and British industries have in common are far better suited to the scale of production in US plants than they are to British operations. Indeed, most US cookie plants may be regarded as exemplifying the classic 'American model' of mass production with shopfloor workers assigned to narrow sets of fairly repetitive tasks. By contrast, in Britain only a small minority of leading plants are able to specialize in the highly automated production of standardized cookies on the same scale as is widespread in the US industry. For the great majority of British plants the pattern of customer demand is such that -- even in the case of basic- and medium-quality cookies -- changeovers of product recipes and machinery need to be much more frequent than in the US. This not only creates difficulties for optimal production scheduling (see Section 5.4 above) but also causes the day-to-day problems thrown up for British process workers to solve to be inherently less repetitive than in most American plants.

Apart from the deployment of low-skilled shopfloor workers, the traditional 'American model' of highly capital-intensive manufacturing is also noted for the key role played by highly-qualified engineering staff in the design and control of production processes (Lazonick, 1990; Chandler, 1990; Broadberry, 1994). We therefore conclude with a detailed assessment of the links between relative productivity performance and engineering skill levels in the respective samples of plants.

6.3 Engineering skills and production flow

In all five countries there was a general preference for machine maintenance staff to hold at least a craft-level engineering qualification, reflecting their responsibility for setting and re-setting of complex wrapping and packing equipment as well as dealing with repairs and servicing of machinery. However, in nearly every case cookie manufacturers looked to the open market for recruitment of skilled maintenance workers rather than develop their own apprentices.

The minimum craft standard was only fully met in Germany (reflecting the high availability of skills delivered by the well-established apprentice training system) and in the Netherlands. Indeed, in Dutch plants roughly half the maintenance personnel had gained technician-level qualifications at intermediate technical (MTS) schools. In both Britain and France about a fifth of engineering workers were vocationally unqualified and regarded as semi-skilled; their recruitment was due to shortages of craft-trained workers in some local areas. In France this deficiency was partially offset by recent recruitment of engineering staff with technician-level qualifications and by the relatively large size of maintenance departments.[11]

In US sample plants roughly 60% of engineering maintenance workers were described by managers as 'journeymen' mechanics and electricians who had followed recognized apprentice training programs equivalent in practice to those in Europe. Although some of the non-journeymen had at least attended relevant trade school and/or community college courses, the proportion of US maintenance workers lacking formal craft-level qualifications was clearly higher than in any of the European industries. However, given the well-known decline of apprentice training in the US

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[11] In terms of hours worked, the ratio of maintenance employment to direct employment was approximately 1:8 in the French sample, 1:9 in the US, 1:10 in Britain and the Netherlands and 1:12 in Germany.

since the 19th century, it is perhaps more notable that American deficiencies in engineering craft skills were not larger still. Engineering maintenance -- so important to the smooth operation of continuous-flow production processes -- is clearly one of the small number of ‘critical trades’ in which the skills and knowledge acquired in apprentice training remain indispensable for US employers.

In a few US plants skill deficiencies among maintenance staff had been partially offset by the employment of four-year graduate engineers as either maintenance engineers or production supervisors. However, as shown in Tables 9 and 10, the total number of graduates in these roles was very small. The main US advantage in the employment of engineering graduates occurred in technical support departments (such as project and quality engineering) and among production managers. Graduate engineers were regularly involved in day-to-day problem-solving on the shopfloor and bore the main responsibility for initiating process improvements (including upgrades of control systems on old equipment as well as the commissioning and installation of new machinery). A striking feature of many such initiatives was their explicit motivation to ‘simplify’ the work of shopfloor employees, for example, by developing easy-to-follow software programs outlining the sequencing of product sampling tests and the corrective actions to be taken by operators under different circumstances.

Table 10: Qualifications held by engineering maintenance workers and technical support personnel in cookie plant samples.

US	BRITAIN	NETHERLANDS	GERMANY	FRANCE
Maintenance workers				
1-2% graduates Approx. 55-65% craft Remainder semi-skilled	80% craft 20% semi-skilled	50% technicians 50% craft	100% craft (with *Meister*- qualified supervisors)	10% technicians 75% craft 15% semi-skilled
Technical support departments				
35% 4-year graduates 5% 2-year graduates	20% graduates 10% technician	5% graduates 30% technicians 30% craft	10% graduates 40% technicians 5% *Meister*/craft	10% graduates 15% technicians 15% craft
Other qualifications not known	70% no vocational qualifications	35% no vocational qualifications	45% no vocational qualifications	60% no vocational qualifications

Note: 'Technical support' staff are defined as those responsible for research, design and new product development, production engineering, production planning, office-based programming and laboratory-based test, inspection and quality control.

Classification of vocational qualifications:
Graduate: US four-year college degrees; British university and polytechnic first degrees and above; Dutch university degrees and HTS certificates; German Hochschulabschluss and Fachhochschulabschluss; French university degrees and higher qualifications.
Technician: British Higher and `Ordinary'-level National Certificate and National diploma awards; Dutch MTS certificates and advanced apprenticeship awards; German Techniker and Meister qualifications; French BTS, DUT and equivalent awards.
Craft: US apprentice-trained journeymen/women; British City & Guilds Part II passes; Dutch LTS certificates and primary apprentice awards; German Berufsabschluss; French CAP, BEP and equivalent awards.

In German plants there was a similarly 'pro-active' engineering policy but this was much more oriented to speeding up production and eliminating bottlenecks and delays than to simplifying the work of production workers. Apart from carrying out regular preventative maintenance, German engineering staff also worked in close collaboration with production supervisors on machinery development and adaptation. Typical examples of the methodical approach to problem-solving in German plants included: the installation of turn-tables for the temporary absorption of cookies if a machine was halted further down the line; modifications to standard wrapping and case-packing equipment designed to reduce both re-setting and maintenance times; the use of overhead cranes to allow flexible reconfiguration of conveyor belts and wrapping machinery; and the in-house development of 'pick up and place' equipment to help cookies pass through multiple secondary processing operations. According to one German manager, it could take 'up to ten years' of incremental improvements to achieve the desired throughput on capital equipment.

Although some examples of efficiency-enhancing innovations were also observed in the Netherlands, France and Britain, they were much less common than in Germany or the US. The majority of Dutch plants benefited from the diagnostic skills of a significant proportion of technician-qualified engineering staff and several French plants had tackled production flow problems by deploying groups of skilled engineering workers to work full-time in shopfloor wrapping and packing departments. However, the majority of Dutch and French supervisors were less well-qualified than German *Meister* to collaborate systematically with engineering specialists on process innovations.

In the British industry, the great majority of production supervisors lacked any form of technical or other vocational training and engineering departments were largely absorbed in dealing with emergency repairs. In some cases these problems required the regular attention of highly-qualified managers and project engineers who were thus diverted from their primary tasks of making long-term improvements in processes and products. Although this bears comparison with the hands-on trouble-shooting role of US engineers which has already been noted, the US plants typically employed larger numbers of technical graduates than their British counterparts and thus had more resources available for knowledge-intensive technical support functions.

Several of the plants visited in each country also had staff members involved from time to time in pre-production testing of new cookie varieties or packaging materials. However, in most cases the bulk of new product development was undertaken in separate research centers detached from production establishments. In this study we have focused primarily on shopfloor machinery and skills. In further research on the determinants of productivity and competitiveness in this industry and other branches of food processing, it would be desirable to pay much more attention to new product development and also to other key functions such as sales, marketing and distribution.

7. Summary and assessment

Estimates of average labor productivity levels in cookie and cracker manufacturing point to continuing US leadership over four Western European industries. Total output (tonnage) per employee-hour in US sample plants was found to be approximately 25-40% higher than in Dutch, French and British samples and about 80% higher than in German plants. In common with the British industry, American cookie manufacturers are heavily concentrated in uncomplicated types of cookies (requiring little in the way of secondary processing and packaging) whereas the Continental European industries – and particularly that in Germany – tend to specialize in more complex, multi-textured products with elaborate packaging. After taking account of estimated inter-country differences in the mix of product-qualities, the US was found to still retain overall productivity leadership; however, in terms of 'quality-adjusted' productivity levels, the estimated US-German differential narrowed sharply to just over 10%.

Higher US productivity levels clearly derive in large part from the greater scope for technical economies of scale in American plants, in particular, their ability to run production lines uninterrupted (without product and machinery changeovers) for much longer periods of time than is typical of European plants. Longer production runs – catering primarily to the large US domestic market --not only help to minimize the time lost due to changeovers but also facilitate more widespread use of both dedicated machinery and automated equipment than in any of the European countries. The American industry did not enjoy any advantage in the newness or sophistication of its physical capital equipment relative to the European samples of plants. However, high production volumes in US plants over the years have supported the installation of much larger-capacity equipment (for example, longer and wider oven-lines) than that typically found in European plants.

The intensity of machinery utilization in US plants (as signified by the incidence of 24 hour shift-working) was second only to that in the British sample. At the same time the average level of emergency downtime in the US sample was well below that in British plants and similar to the average rate of downtime in Germany, France and the Netherlands. This partly reflected the willingness of many American production managers to tolerate equipment malfunctioning -- and associated product wastage -- in order to meet inflexible corporate production targets and to secure the overall cost advantages of long, uninterrupted production runs. However, it was also associated with preventative maintenance practices which in most US plants were closer to those in Continental Europe than in Britain.

In all five industries a large majority of shopfloor employees were engaged in low-skill wrapping and packing work. The most pronounced differences in shopfloor skill levels were found in process departments covering the mixing and baking stages of cookie production. For example, German plants specializing in small- and medium-batch production of high-quality multi-textured cookies depended greatly on the know-how and experience of craft-skilled bakers in their process departments. By contrast, in the American and British samples, process work was largely designated as ‘semi-skilled’ reflecting their primary orientation towards longer runs of relatively simple (undecorated) types of product. American and British process workers were also typically allocated to single task areas on individual oven-lines whereas their German counterparts were able to move flexibly between different task areas on two or more oven-lines. In relation to these German and US/British extremes of product strategy, process skills and work organization, the Dutch and French samples both occupied intermediate positions.

In all five countries there was a general preference for machine maintenance staff to hold at least a craft-level engineering qualification, reflecting their responsibility for setting and re-setting of complex wrapping and packing equipment as well as dealing with repairs and servicing of machinery. However, this minimum standard was only fully met in Germany and in the Netherlands. In both Britain and France about 80% of engineering maintenance workers were craft-skilled and in the US sample the proportion of ‘journeymen’ maintenance workers was only about 60%. A key responsibility for the smooth operation of continuous-flow production lines in US plants was undertaken by graduate engineers who were regularly involved in day-to-day problem-solving on the shopfloor and bore the main responsibility for initiating process improvements. Graduates represented some 35% of total employment in technical support departments in American plants as compared with 5-20% in the European samples.

The US cookie industry thus exemplifies the classic ‘American model’ of production organization with highly-qualified engineering staff closely involved in the design and control of production processes while shopfloor workers are assigned to narrow sets of fairly repetitive tasks. A striking feature of many process improvements initiated by American engineers was their explicit motivation to ‘simplify’ the work of shopfloor employees still further, for example, the development of easy-to-follow software programs outlining the sequencing of product sampling tests and the corrective actions to be taken by operators under different circumstances.

In general the relatively low shopfloor skill levels (and associated patterns of work organization) in the US industry appear to be far better suited to the scale of production in US plants than they are to the ostensibly similar British industry. For all but a small minority of British plants, the pattern of customer demand is such that -- even in the case of basic- and medium-quality cookies -- changeovers of product recipes and machinery need to be much more frequent than in the US.

In contrast to many other branches of US manufacturing, most American cookie producers are not under significant pressure from imports of standardized products to shift towards smaller-batch, high value added types of output. Hence in this industry the scale-economies associated with traditional mass production techniques look set to underpin continued US leadership in labor productivity.

APPENDIX A: Estimates of 'quality-adjusted' productivity levels

A standard approach to the measurement of product quality differences is to define such differences in terms of technical characteristics. For example, 'hedonic' regression techniques are often used to estimate 'shadow prices' for goods with a specified list of characteristics (such as, in the case of motor cars, length, width and engine capacity). As noted in Section 4 of the main text, the detailed information we had gathered during cookie plant visits enabled us to classify each plant's output into four different grades of product defined in terms of the number of processes involved in their production and the types of ingredients and packaging materials used:

1. Basic-quality, single wrapping: 'dry' undecorated cookies or crackers made from relatively cheap ingredients (e.g. vegetable or animal fats), stacked in cylinder-form and wrapped in a single layer of plastic film.
2. Basic-quality, multiple wrappings: as described for Grade 1 but with more than one layer of packaging.
3. Medium-quality: cookies requiring at least one secondary production process after baking such as chocolate-coating or sandwich-filling with cream or jam; usually sold with at least two layers of packaging. Undecorated cookies made with more expensive ingredients such as butter are also included in this category.
4. High-quality: elaborate, multi-textured cookies requiring two or more secondary (post-baking) production processes, usually stacked in successive small piles, multi-wrapped and boxed; includes assortments of cookies made from expensive ingredients.

In the earlier intra-European comparison (Mason et al, 1994), only three different quality-grades were defined, namely, grades 1, 3 and 4. However, the US sample of plants turned out to be characterized by a relatively large share of output consisting of ostensibly 'basic-quality' cookies and crackers (that is, undecorated products not subject to any secondary production processes) which nonetheless were invariably produced with multiple layers of packaging (in contrast to the single wrappings typically used for such products in Europe). Accordingly, a new quality grade (No. 2 above) was defined to cover this distinctive American product category.

As a first step towards the calculation of a 'quality-adjusted' measure of output in each industry, an index of average retail prices in each country was then compiled using price data (net of sales prices) for the different grades of cookies/crackers in each country, based on products observed in the plants visited. As shown in Table A1, Part 2, average retail prices of closely-matched products in the 'basic quality - single wrapping' grade in each country were used to provide a numéraire for these cross-country price comparisons. Subsequently, in order to obtain estimates of inter-country differences in the average value added per ton of output, this index of average retail prices was converted to an index of average ex-factory prices on the basis of estimated average retail gross margins (exclusive of sales taxes) in each country, and a rough index of value-added per ton was then derived by recalculating the index of average ex-factory prices on a 'net of raw materials' basis using Production Census data on inter-country differences in the shares of production costs relating to intermediate inputs such as ingredients, fuel and packaging materials (see Table A2, Note C).

As described in the main text, these calculations suggested that average value added per ton of cookies and crackers in Germany was substantially higher than in the other four countries. When this value-added index was combined with our earlier measures of (crude) output per employee-hour in each national industry, 'quality-adjusted' productivity levels in the German industry were found to be only 10% below those in the US (Table A3, Row 3) -- a substantially smaller differential than the 45% gap between the two countries in crude output (tonnage) per employee-hour. Alternative calculations using unweighted sample output and employment data yielded very similar estimates of average value added per employee-hour (Index numbers: US=100): Germany 90, Netherlands 80, Britain 65, France 65.

In summary, although the measure of 'value added' employed here is clearly very approximate, the orders of magnitude conveyed by these estimates leave little room for doubt that inter-country variation in the mix of product-qualities makes a significant contribution to international differences in real productivity levels in this industry.

Table A1: Distribution of quality-grades of cookies and their relative prices in the United States, Britain, the Netherlands, Germany and France.

All numbers rounded to nearest five

	US	BRITAIN	NETHERLANDS	GERMANY	FRANCE
1. Distribution of output (tonnage) by quality-grade in national samples of cookie manufacturers (a)					
			(Percentage shares of output)		
Basic-single wrapping	15	35	25	15	20
Basic-multiple wrappings	30	0	0	0	0
Medium	50	60	60	50	70
High	5	5	15	35	10
TOTAL	100	100	100	100	100
2. Average retail prices of cookies by quality-grade (b)					
			(Index numbers: Basic-quality=100)		
Basic-single wrapping	100	100	100	100	100
Basic-multiple wrapping	135	na	na	na	na
Medium	205	200	250	310	220
High	325	360	370	660	420
3. Average retail prices of cookies produced by national samples of manufacturers					
			(Index numbers: US =100)		
Average retail price per ton (c)	100	100	130	230	125

a: See text for details of quality-classification.
b: Based on average retail prices (net of sales taxes) of packets of 250g (occasionally 125-450g, with proportionate adjustments) in 1991 in European countries and 1994 in US. Price of matched basic-grade products set at 100 for each country. All cookies purchased in medium-sized supermarkets in each country.
c: Average of the three retail price-ratios for each country shown in part (ii) of table, weighted by output-proportions shown in part (i); expressed as index with US = 100.

Table A2: Estimates of average retail and ex-factory prices of cookies produced by national samples.

	US	BRITAIN	NETHERLANDS	GERMANY	FRANCE
			(Index numbers: US =100)		
Average retail price per ton	100	100	130	230	125
Average ex-factory price per ton	100	100	115	175	115
Average value added per ton	100	95	105	165	110

a: See Table A1, part 3.
b: Based on index of average retail prices, as shown in previous row, with adjustments for estimated inter-country differences in average retail gross margins based on information supplied by cookie industry sources. Gross margins as a percentage of total cookie retail sales value in Britain averaged an estimated 15%, with wide variations from about 5% for the most basic varieties to 25% for the higher-quality cookies. Information gathered in the other three countries was consistent with an assumption that average retail gross margins were roughly proportional to inter-country differences in average retail prices, as follows: Britain 15%, US 15%, Germany 35%, Netherlands 25%, France 20%.
c: Based on index of average ex-factory prices, as shown in previous row, with adjustments for inter-country differences in average ratios of materials costs to total ex-factory sales value of goods produced in cookie manufacturing (based on Production Census data for each country; 'materials' are those used for production, packaging and fuel; 'sales value of goods produced' defined as Gross Output less value of goods merchanted or factored).

Table A3: 'Quality-adjusted' measures of labor productivity in cookie manufacturing.

	US	BRITAIN	NETHERLANDS	GERMANY	FRANCE
			(Index numbers: US =100)		
Output (tons) per person-hour	100	70	80	55	70
Value added per ton	100	95	105	165	110
Quality-adjusted output per person-hour	100	65	85	90	75

Appendix Table B1: Age-distribution of machinery in national samples of cookie plants.

Employment-weighted percentage shares, rounded to nearest five per cent

	Preparation and mixing equipment			Ovens			Wrapping/packing machinery		
	<5yrs	5-10	>10	<5yrs	5-10	>10	<5yrs	5-10	>10
BRITAIN	30	20	50	15	15	70	25	35	40
NETHERLANDS	5	5	90	5	5	90	20	40	40
GERMANY	20	20	60	15	35	50	40	40	20
FRANCE	20	10	70	30	10	60	50	25	25
UNITED STATES, 1990/91	20	20	60	20	25	55	30	25	45
UNITED STATES, 1993/94	20	15	65	15	20	65	20	30	50

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