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International differences in productivity?
Coal and steel in America and Britain
before World War 1*

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The assumption that the New World has yielded unusually high returns to the factors of production has been a part of our thinking from the time of Adam Smith and before. It is a congenial assumption, suggesting as one might wish that the right to life, liberty and the pursuit of happiness had material as well as moral advantages. The evidence for it, however, has been collected somewhat casually. In the nineteenth century Anglo-American comparisons were made with scattered data on real wages, that is, data on labour's marginal product. After the first British census of production in 1907 they were made with data on labour's average product. In either case the comparisons reflected the productivity of one factor of production alone, although, to be sure, the excess of American over British labour productivity was so large that it appeared that no reasonable allowance for larger inputs of other factors could account for it. The findings for the 1920s of A. W. Flux, the director of the British census, that real value-added per worker in British manufacturing was half the American average was confirmed in later studies by L. Rostas for the late 1930s, by M. Frankel for the late 1940s and, most thoroughly, by a series of studies by the Organization for European Economic Co-operation and the Cambridge Department of Applied Economics on real national income in Europe and America for the early 1950s [1]. The OEEC-Cambridge studies, which were based on careful international comparisons of price levels rather than on the par exchange rate and included all sectors of the economy rather than manufacturing alone, found that British gross national product per worker was about half the American level and value-added per worker in manufacturing alone was still lower [2].

In his study of *Why Growth Rates Differ* Edward Denison attempted to explain this gap in the levels of income per worker for 1960 [3]. The

gap between the United States and the United Kingdom was then 41 per cent of the American level. He found that only 11 percentage points of it could be explained by total factor input corrected for quality and a mere 0.7 percentage points by misallocation and economies of scale; the rest, or about three-quarters of the total gap in 1960, had to be attributed as a residual to 'lags in the application of knowledge, general efficiency and errors and omissions' [4]. This result is both disappointing and remarkable. It is disappointing because it implies that even an imaginative use of conventional economic theory leaves the greater part of productivity differences unexplained [5]. It is remarkable because it implies that the productivity of the British economy was very far behind: as Denison put it, the level of total productivity, after allowing for economies of scale, the quality of the labour force, misallocation and conventionally measured inputs of capital, was about 20 per cent lower in the United Kingdom in 1960 than it had been in the United States in 1925. The gap was apparently a large, persistent fact.

Explanations of the fact have consumed many hours of after-dinner conversation, and their origin in the mental haze of brandy and cigars is sometimes apparent in their printed expression. After a nod towards the evidence, the writer loosens his tie and his standards of logic, and launches on one of several speculations. In reading the literature of Anglo-American comparison, one is struck by the attraction that certain of these speculations appear to have, irrespective of their empirical merit: repeatedly the story is told of cheap land causing mechanization, a large free-trade area encouraging economies of scale, rapid growth of industrial plant permitting the use of the most modern equipment in the New World, and the inevitable 'clogs to clogs in three generations' crushing the spirit of enterprise in the Old.

The persistence of the gap through many generations creates difficulties for some of these. For example, it is plausible perhaps that the vigour of an immigrant population yielded higher productivities, but the mass immigrations were confined to the second half of the nineteenth century, too late to explain any American superiority before 1850 and too early to explain it after 1920. Allyn Young, among others, doubted that there was evidence of greater vigour in the United States and supposed instead that economies of national scale were the dominant factor [6]. On the other hand, as E. Rothbarth pointed out, the scale of the American economy was not always larger than the

British [7]. He suggested that the higher ratio of land to labour was the true cause of American superiority. Yet land was not always an important factor of production: indeed, by the time estimates of factor shares are available, in the late nineteenth century, the share of land in national income was well below 10 per cent in the United States and below 15 per cent in the United Kingdom [8]. Though for particular industries, as will be shown later, the amount and quality of land in the United States may explain high labour productivities, for the economy as a whole it is doubtful that it can. If the arguments had been framed in quantitative terms, such difficulties as these would have been immediately apparent and would have inspired more critical examination of the explanations of American superiority, but they have generally been left in the pre-quantitative form in which the after-dinner speakers first expressed them. And many of them, of course, do not seem to fit easily into quantitative categories. This is especially true of the assertion, which has done good service as a residual explanation when others have proved wanting, that American businessmen were able to seize and retain a technological lead over Europe.

It is not generally recognized how puzzling would be the existence of a persistent and large American technological lead. If the difference between American and British production functions were as little as 10 per cent, say, and the share of entrepreneurial returns in total costs as much as 30 per cent, the adoption of American methods would increase returns to entrepreneurship by at least a third: a British firm could reduce its costs by 10 per cent and take the reduction in additional profit [9]. With the easy transport and communication that developed during the nineteenth century between the United States and the United Kingdom, with the frequent migrations of managers and the absence of a language barrier between the two, and with the competitive markets of both, it is hardly credible that such a large reward for imitation would go unclaimed. Recently D. W. Jorgenson and Z. Griliches have expressed scepticism about the significance of technological change, or costless increases in output for a given input, over time, asserting that 'the accumulation of knowledge is governed by the same economic laws as any other process of capital accumulation. Costs must be incurred if benefits are to be achieved' [10]. If this view has some plausibility for technical change between two years it has still more for technical differences between two countries. Investment in imitation is surely a less risky undertaking than investment in research,

especially when the imitation can take the form of the mere purchase of improved machinery or the hiring of better managers from the leader. It would be strange if large technical differences persisted.

But this line of reasoning seems to be contradicted by the large, persistent gap in residual productivity [11]. The national comparisons of Denison register a gap of 35 per cent between the average levels of total productivity in the two countries and the earlier studies of labour productivity suggest that the same order of magnitude of difference has existed for a century and a half. One necessary downward revision should be mentioned. National comparisons give an exaggerated impression of the typical degree of American superiority. To get a true impression the comparisons must be made at the level of industrial detail corresponding to individual firms, because the national comparisons ignore intermediate inputs. If the United States had typically a 20 per cent advantage in efficiency, the advantage would be amplified by the cheapness of intermediate inputs, yielding a national productivity difference larger than 20 per cent [12]. If the United States, for example, produced iron ore and coal, as well as finished iron and steel, with 20 per cent less inputs than the United Kingdom did, the total direct and indirect resource costs of American iron and steel would be more than 20 per cent less than British resource costs. Put the other way, the national difference of 35 per cent in productivity corresponds to a smaller difference at the level of industrial detail where comparisons of costs and decisions to innovate take place. This is the level of the firm. The higher the typical share in total costs of purchases from other firms, the lower will be the productivity difference. In the United States the share was around 44 per cent of costs, implying a typical difference in productivity of about 20 per cent [13].

A gap of 20 per cent is still large. In view of it, one strategy of research would be to examine in detail the channels of technological flow in an attempt to find where they were blocked. Another, which will be pursued here, is to subject the difference in productivity to creative disbelief. The working hypothesis for this task is that British and American industries operated on substantially the same production functions. The appropriate production functions are those for the products of individual industries including materials in costs as well as value-added. For practical reasons the industries must have easily measured inputs and outputs and must be few in number. To offset their fewness they must be large. In order to put the working hypothesis in the most jeopardy, finally, they should be industries whose

technological performance in late nineteenth-century Britain by the conventional measures was bad. Two industries that satisfy these requirements are coal and steel.

COAL

Historical opinion on the performance of the British coal industry before 1913 is not uniformly unfavourable. The industry grew much more slowly than the American or German industries, but there are adequate explanations from the side of demand for this, as there is for the worldwide shrinkage in the market for coal after the early 1920s, an event that casts a shadow back on the prewar history of the industry. Clapham, for example, concluded that in the quarter century before 1913:

> The whole industry, though full of conflict, was active and expanding both commercially and geographically. Its best units were admirably equipped. . . . [14]

Still, he noted that most British mines ignored equipment that had become common abroad. The mechanical coal-cutter is the best known, but the list includes as well steel pit props, electric haulage of coal and concrete and cement liners for shafts and tunnels. A. J. Taylor, the leading student of the industry, has emphasized these deficiencies, and his views are more representative of historical opinion on the matter than Clapham's. He mentions diminishing returns to land and other extenuating circumstances, yet concludes that

> It is still valid to speak of a hard core of recognizable inefficiency existing in the pre-1914 coal industry . . . in terms of diminished labour effort, unwillingness to accept innovation and the failure to provide a structure for the industry suited to the opportunities and needs of the twentieth century. . . . In all this the experience of coal was no doubt symptomatic of trends which were widely operative in British industry, more particularly in its older and deeper rooted sectors. [15]

This assertion does not bear up under close examination.

The chief evidence that an unwillingness to accept innovation altered the industry's history is that after the 1880s output per man-year in British coal mining declined, which, were this by itself an acceptable

measure of productivity, would certainly suggest that there was an important failure of spirit in industry. The evidence of productivity is certainly more relevant to the issue than selected cases of the slow adoption of new equipment: indeed, the only way to determine whether the equipment was an important and profitable novelty is to perform a productivity calculation before and after its adoption. The average product of British labour, however, is a poor indicator of the course of British productivity. Average product fell, to be sure, but it fell or stagnated everywhere in Europe before World War I and does not suggest therefore any peculiarly British failure [16]. On the contrary it suggests that the natural conditions of coal mining dominated the determination of the average product of labour, driving it down as the coal beds were depleted. The rise in the average product in the United States during the period does not contradict this interpretation, since American coal reserves were so enormous that their depletion, except in the anthracite region, was negligible [17]. And comparisons of the level of the average product in various countries confirm it, suggesting that American product per man was high because the margin of cultivation of coal reserves had not been pushed far and that Belgian product, for example, was low because the margin had been pushed very far indeed. In comparing American and British productivity, however, most observers have resisted attributing all the difference in labour's average product to differences in the input of land. A resolution of the issue requires an estimate of how large the impact of the quantity and quality of cooperating factors was on the average product of labour.

The estimation of the average product of British and American labour is not as straightforward as the mass of statistics on the industry, the result of thorough and sustained official scrutiny in both countries, might lead one to hope. The data requirements of productivity measurement are great and in making comparisons between countries the sources of error are great as well. The output of coal, for example, seems to be a simple concept, but is not. Differences in the quality of coal mined may bias the measurement of output in one country in terms of another, because coal with good qualities and therefore high value per ton warrants more intensive mining at higher cost — that is, lower productivity. A similar problem afflicts the measurement of labour input. Ideally each quality of coal and labour should be weighted by its economic value in one country to form an index for one country in terms of the other, but the data are not good enough to do this [18]. Even the comparison of the crude aggregates, presented in

Table 1, which is based on the British Census of Production 1907 and the American Census of Mines and Quarries of 1909, is difficult. Through the statistical haze, nonetheless, comes the impression that output per man in Britain was half or perhaps a little more than half that in America before World War I.

The input of capital cannot explain any of this difference, since capital per man was about the same in the two countries. Horsepower

TABLE 1
Yearly output per man employed, U.K. 1907 and U.S.A. 1909

	Output (millions of long tons)	Wage earners employed (millions)	Tons of output per wage earner year
U.K.	267	.812	325
U.S.A.	408	.667	613

Sources:
U.S.A.: U.S. Bureau of the Census, Thirteenth Census, vol. XI, *Mines and Quarries 1909* (Washington, D.C., Govt. Printing Office, 1913), pp. 186 ff. The employment figure given on p. 186 excludes coke workers, as it should to be comparable with the British figure. It relates to 15 December. December, however, was the month of peak employment in the industry (100 compared to 93.4 for the entire year; ibid., p. 30). The figure given here is corrected for this overstatement.

U.K.: Board of Trade, *Final Report on the First Census of Production of the United Kingdom (1907)* (London, H.M.S.O., 1912), pp. 42 ff. The employment figure has been reduced by an allowance for iron miners working in mines under the Coal Mines Regulation Act (which are included in the definition of the coal industry in the British census). It relates to four Wednesdays during the year and reflects the normal absenteeism of 10 per cent: the census figure is roughly 10 per cent below the Home Office figures, which relate apparently to people employed whether actually working or not. The hours worked per year by each of these wage earners was probably somewhat higher in the U.K. than in the U.S.A.; the eight-hour day was introduced in unionized mines in the U.S.A. in 1898 and by 1909 the day was 8.6 hours (U.S. Geological Survey, *Mineral Resources of the United States 1922* (Washington, D.C., Govt. Printing Office, 1925), p. 503). In the U.K. the eight-hour day was introduced in 1908, after the census.

per man, for example, according to the census data was virtually identical in the two: 2.82 per man in Britain and 2.85 in America. Horsepower statistics are very crude measures of capital, since they reflect only the stock of a certain kind of equipment rather than all equipment, structures and inventories together, yet there is reason to accept their surprising testimony that high American wages did not lead

to higher capital per man. The reason is that capital was a substitute for land as well as labour: bad and expensive coal land, such as Britain had relative to America, could be worked profitably only by investing in deep shafts and long tunnels to ferret out the coal. This heavier capital investment meant, for example, that British mines were much larger than American mines. It is plausible, then, that the substitution of capital for labour in the United States was matched by a substitution of capital for land in the United Kingdom. In any case, only if the measure is very much in error would capital have any great effect on output per man because capital's share in total costs was small. In the United Kingdom its share was around 12 per cent and in the United States only 4 per cent [19].

Land's share was small, too, but its small weight in the calculation of productivity was offset by the enormous differences in its quantity and quality in the two countries. The ideal measure of land input, like the ideal measures of coal output and labour input, would add up different units weighted by their value in producing coal [20]. This value — the coal land's price — is determined by characteristics such as its closeness to consumers, the ease of mining it, and the quantity of coal it contains. If the separate effects on price could be measured with acceptable accuracy, the production function, as it were, for land in terms of these characteristics of quality could be written down and the land input in the two countries compared precisely. The price of coal land classified by quality, however, is not available. Fortunately, the case to be made here, that differences in resource endowments explain most of the difference in output per man, can rest on a very rough approximation to the ideal programme.

The sheer quantity of coal land per worker was clearly larger in America than in Britain. The exact meaning of the 'sheer quantity' of land is somewhat elusive. Is it coal land in existence or coal land in use, tons of reserves under the ground or acres of land on the surface? The unit of measurement chosen should satisfy the specification of the production function that doubling it and all other inputs results in a doubling of output. Moreover, the unit represents a property right that is bought and sold and should therefore correspond to the unit employed in these transactions. The situation is obscured by the differences in mineral property rights in America and Britain: in America the surface land and everything under it was sold as one, while in Britain the surface and mineral rights were sold separately, often to the extent of selling different seams under one surface to different mining com-

panies [21]. A reasonable compromise is to take the right to mine a certain quantity of tons of coal reserves as the unit of land. In any case, it should be the number of the units, however defined, that mining companies actually own or lease. Land that contains coal but is not considered worth holding by the coal companies should not be included in the coal industry's inputs. The American census gives acres of coal land owned or leased by the industry, but the British census does not and there is no corresponding statistic available in other sources. There are no statistics on the land 'in use', however, that might be defined. The only alternative is to use the tons of reserves in actively mined regions as an estimate of the land employed in the industry [22]. This is a crude procedure and it is prudent therefore to bias it in the direction of lowering the American measure of land employed. Accomplishing this by using in the measure only the reserves of the six most intensively mined states (Pennsylvania, West Virginia, Ohio, Indiana, Maryland and Arkansas), American land input in 1910 in terms of reserves was about 400,000 million metric tons [23]. Total reserves were eight times this: many of them lay fallow in the Rocky Mountains, to be sure, but the reserves of such large coal producing states as Illinois and Kentucky are also excluded from this figure. In comparable units, the entire reserves of the United Kingdom, whether intensively mined or not, were about 100,000 million metric tons [24]. British land input, then, was a quarter of the American and land input per worker was in the ratio of 0.205 to 1.000. The difference is about 80 per cent of the American level of land per worker. The difference in output per worker was 47 per cent of the American level. Since the share of land was about 0.08 in costs, the difference in the quantity of land per worker explains about 6.4 percentage points of the total difference of 47 points.

Not only was the quantity of coal land large in America compared with Britain, but, more important, its quality was high. American seams were generally thicker, closer to the surface, freer from faults, flatter and drier than British seams [25]. American coal land in 1910 had been blessed with a fortunate geological history and a brief industrial history. In using the meagre data to count these blessings, it is important to keep in mind that the quality of land to be worked was to some extent a matter of choice. If unusually thin seams were to be worked profitably in competitive circumstances they must have been unusually close to the surface, have been unusually free from faulting, or have had some other compensating virtue. Thick seams, on the other hand, would have been worked at great depths and with very faulted con-

tours [26]. The result is that a simple plot of output per man against one of these qualities (such as thickness, shallowness, faultlessness) will give an impression of the impact of the quality biased towards no impact at all: as the thickness of seams rise, for example, their average depth will increase, reducing on that account output per man and resulting in an understatement of the true impact of changing thickness alone. It is important, therefore, to hold the other variables constant [27].

There is widespread evidence that in the range usually observed the thickness of seams had a large effect on output per man. One of the few opportunities to control for depth as well as thickness for a good sized sample is the data collected for forty-eight American shaft mines by Carroll Wright as Commissioner of Labor in his *Sixth Annual Report 1890, Cost of Production: Iron, Steel, Coal, etc.* [28]. A regression of output per man on thickness, depth, and the size of the screen separating coal into 'screenings' and more valuable large sizes, yielded an R^2 of 0.39, which is hardly impressive, and a coefficient on depth insignificantly different from zero. It is not too surprising that in the shallow American mines depth was unimportant (the average in Wright's sample was only 178 ft compared with a British average of around 1000 feet) [29]. The effect of seam thickness, however, is clear and strong: the coefficient is five times its standard error and the elasticity of output per man with respect to seam thickness is over 0.5. The weight of evidence, indeed, is that the effect of thickness was even greater, with an elasticity of around 1. In an unusual sample of outputs per tonnage worker and seam thicknesses collected for 1921 in Illinois, for example, the implied elasticity in the range of 5.5 ft is about 1.2 [30]. The consequences are important. The average seam worked in Britain in 1924, when the matter was first investigated systematically, was 50 in; the average in America in 1920-2 was about 65 in [31]. With an elasticity of about 1, this difference would explain about 25 percentage points of the total difference of 47 per cent in the average product of labour.

The 15.6 per cent difference remaining after the effects of land and thickness are extracted is more than explained by the great depth of British mines. The effect of depth can be approached through its close correlation with thickness. In contrast with the United States, in which the distances between coal markets created wide divergences in price, the United Kingdom was one market for coal. The market as well as technology worked to limit the dispersion of behaviour in the industry.

All combinations of thickness and depth could be observed in the United States because a poor combination was protected by the distance to a competitor. British mines, however, were all forced to lie close to the same curve of equal average product relating thickness and depth [32]. The slope of this curve expresses, then, the change in thickness required to compensate for a given change in depth. The elasticity of thickness with respect to depth appears to have been in 1924 about 1.2 [33]. Since the average depth of mines in the early 1920s was about 1000 ft in Britain and only 280 ft in the United States, the equivalent change in thickness is very high. Any reasonable elasticity of output per man with respect to thickness, then, will permit the depth of the coal to explain the remaining difference in average product. Indeed, the quantity and quality of land available to the American industry explains much more than is necessary to absolve the British industry of the charge of failure, especially in view of the biases introduced against this hypothesis in the course of the argument. A weaker argument, weighted still more against the hypothesis of British competence, would suffice.

The exercise is crude, to be sure, but its very crudeness suggests that it requires no delicate and uncertain inquiry to explain the difference between labour productivity in the American and British industries in terms of the large differences between the resources with which the two worked. The case for a failure of masters and men in British coal mining before 1913, in short, is vulnerable to a most damaging criticism: there was clearly no failure of productivity.

STEEL

It is commonly believed, with even more conviction than for the coal industry, that the steel industry in late nineteenth-century Britain performed poorly. The managers in coal could be excused on the grounds that the quality of the natural resource with which they worked was deteriorating, but the steelmakers could not: indeed, the chief history of the industry, D. Burn's *The Economic History of Steelmaking 1867-1939* [34], faults them for ignoring, in the phosphoric ores of Lincolnshire, the natural resources they did have. Burn emphasizes repeatedly the 'personal deficiencies', 'attachment to routine', and 'inadequate education' of British managers, and T. H. Burnham and G. O. Hoskins in their history of the industry sum up a similar indictment as follows: 'There is, in fact, good evidence to

believe that the British iron and steel industry would not have declined so fast or so far during the period reviewed had the men at the head possessed greater vision and a bolder and more energetic capacity for organization, direction and administration' [35]. This view of the industry is widely accepted. The steel industry, in fact, almost invariably plays a large role in discussions of American technological superiority. If most observers believe that British coal mining was inferior, virtually all believe that British steelmaking was.

The evidence for a large technological difference in steel, as in coal, is dubious and it is fairly easy to show that the difference did not exist. In coal it was convenient to begin with the average product of labour in measuring productivity, since labour costs were 60 to 70 per cent of the total. In steel the direct costs of labour were much smaller. Most of the costs were materials, especially pig iron, but because the materials were used in relatively fixed proportion to output during the period the measure cannot use their average product. In any case the data on quantities of labour and pig iron used in steel production are poor. The way around this obstacle is to use the inputs' prices relative to the price of output rather than their quantities — that is, their marginal rather than their average products [36].

The best sources for comparing prices of inputs and outputs in steel, as for comparing their quantities in coal, are the prewar censuses of production in the United States (1909) and the United Kingdom (1907). Market prices reported regularly in the trade journals are useful checks, but the census data has the critical advantage of wide coverage. Wide coverage has drawbacks, too, often concealing rather than curing the heterogeneity in such categories as 'American pig iron' or 'British wage earners'. Market prices, in contrast, refer to a specific commodity at a specific location sold under specific terms, although it is often difficult to determine exactly what these specifications were. The average values in the censuses, then, must be handled with care. For example, the British census gives values and quantities for 'thick plates', which include ship plates and boiler plates, while the American census gives data for 'plates and sheets', which include sheets as well. Since sheets required much more rolling than plates, they were more expensive per ton and their effect of raising average values must be removed if the American industry is not to appear spuriously inefficient [37]. A similar problem of heterogeneity occurs in the measure of pig iron input. Low phosphorous (or 'acid', 'Haematite', or 'Bessemer') pig iron was more expensive because it was cheaper to use and more costly to

make than other varieties. Because the British industry used more of it than the American industry the categories given in the censuses must again be broken down into more detail to avoid spurious productivity differences [38].

The results of the various corrections are exhibited in Table 2, which gives the names and average values of comparable American and British products. The values that it was necessary to estimate are bracketed. The marginal product of pig iron implied by this table — that is, the ratio of the price of pig iron to the price of a steel product is invariably

TABLE 2
Rolled iron and steel:
census values of labour and pig iron inputs and major products

U.S.A. 1909		U.K. 1907	
American name	*American value*	*British name*	*British value*
(dollars/ton or man-year)		(shillings/ton or man-year)	
Bessemer pig iron	[$15.70]	Haematite pig iron	72.5s.
Other pig iron	[$14.68]	Other pig iron	55.4
Average, all pig used	$15.10	Average, all pig used	[65.3]
Yearly earnings, wages	$679	Yearly earnings, wages	[1690s]
Plates ≤ gauge 16	[$36.10]	Plates ≤ 1/8″ thick	138.7s.
Rails	$28.38	Rails (including train	
Bars and rods	$31.97	rails	120.0s.
Structural shapes	$30.90	Steel bars, angles	133.8
Black plates and sheets	49.00	Girders, beams	128.0
		Black plates and sheets	188.0

Source: The source for the U.S.A. is the 1909 Census, pp. 238—40, and for the U.K. the 1907 Census, pp. 101—3 (see sources for Table 1). The coverage is roughly half of the value of rolled products and steel (i.e. excluding cast iron) in both the U.K. and the U.S.A. The bracketed figures were estimated as described in previous footnotes. The U.K. average value of pig used was estimated from the average values given in the Census (for forge and foundry, haematite, and basic) weighted by estimates of the haematite and non-haematite pig iron used to make steel and wrought iron (i.e. excluding cast iron and exported pig iron). These estimates, in turn, were based on the acid/basic proportions of steel output and an assumption that all puddling was done with non-haematite pig.

higher in Britain. This is not surprising, since labour was, of course, much cheaper relative to pig iron in Britain than in America, causing labour to be used intensively and raising the marginal product of pig iron. What is surprising, in view of the usual assumption of overwhelm-

TABLE 3

Productivity differences for major steel products

	Marginal products of pig iron		% difference in marginal products of pig iron (U.S.A. higher = +)	% difference in total productivity (U.S.A. higher = +)
	U.S.A.	U.K.		
	1	2	3	4
Heavy plates	.418	.471	−11.92	−1.57
Rails	.533	.545	− 2.22	+8.13
Bars, rods, etc.	.473	.488	− 3.13	+7.22
Structural shapes	.488	.510	− 4.41	+5.94
Black plates and sheets	.308	.348	−12.20	−1.85

Source: Table above. Columns 1 and 2 are the average price of pig iron divided by the price of the product. Column 3 is $[(1) − (2)]/[1/2(1)+1/2(2)]$. Column 4 is column 3 minus the share of labour (assumed to be 0.192, which is the American value and is high for the U.K.) times the percentage difference in the price ratio of labour to pig iron (W/P). That is, column 4 is (denoting percentage differences in the variables with asterisks)

$$A^* = (P_I/P)^* + S_L(W/P_I)^*$$

The result assumes that labour and pig iron are the only two factors of production. In the United States they accounted for about 0.68 per cent of the costs of production, excluding steel inputs into steel in the total cost.

ing American superiority, is that this higher marginal product of pig iron in Britain is not outweighed by a correspondingly lower marginal product of labour. That is, as shown in Table 3, the uniformly high price ratio of pig iron to steel in Britain was just barely offset by a uniformly low price ratio of labour to pig iron, leaving very small differences in the total productivity of the American and British industries.

On this reckoning, which agrees with the pattern of comparative advantage that might be expected, the American industry was slightly superior in the making of rails, bars and structural shapes, and the British industry in the making of plates and sheets. The assumption that the share of labour was the same for each product when it was not imparts a small bias to the results, as can be seen from the steady relative improvement of British performance as the degree of fabrication (and labour-intensity) increases from rails to sheets. If this bias were corrected, the productivity differences would be more uniform from product to product, with perhaps a 2 or 3 per cent average superiority for the American industry.

The negligible difference in output for a given input suggests that entrepreneurial failure had little to do with the relative positions of the British and American supply curves, especially in view of certain biases against the British industry in the measure. Two years of productivity growth between the years of the British and American censuses would account for some of the difference. Moreover, 1907 ánd 1909 in the two countries were at different stages of the business cycle. The productivity measurements assume that the industries were in long run equilibrium, that is, that their cost curves were horizontal. When a cyclical increase in demand has raised output to a new peak, straining capacity, this assumption is violated and productivity appears lower than it is. It is likely, in fact, that the British industry suffered more from this downward bias in the measure [39]. In any case, though the measure in steelmaking as in coal mining is crude, the result is plain: the total productivities of the American and British industries before the War, when the allegations of American skill and British ineptitude were already many decades old, were virtually indistinguishable.

The apparent lack of any failure of productivity in coal and steel suggests that the traditional contrast between managerial vigour in America and sloth in Britain may be in need of critical re-examination. The measures of productivity proposed here are far from perfect and apply to only two industries. Yet the alleged superiority of American over British technique does not register in either, even though the superiority in coal and steel has usually been thought to have been especially great. Apparently, technology in these two industries was international. This is not a very surprising conclusion, given the sample means of communicating knowledge and the strong incentives to use it. In this view, the differences between the Old World and the New were differences in the quantity and quality of inputs, not in vigour and technology.

NOTES

[1]   A. W. Flux, 'Industrial productivity in Great Britain and the United States', *Quarterly Journal of Economics*, 48, November 1933, pp. 1–38; L. Rostas, *Comparative Productivity in British and American Industry* (Cambridge, Cambridge University Press, 1948); M. Frankel, *British and American Manufacturing Productivity* (Urbana, University of Illinois Press, 1957); M. Gilbert and I. B. Kravis, *An International Comparison of National Products and the Purchasing Powers of Currencies* (Paris, OEEC, 1954); M. Gilbert *et al., Comparative National Products and Price Levels* (Paris, OEEC, 1958); D'. Paige and G. Bombach, *A Comparison of National Output and Productivity of the United Kingdom and the United States* (Paris, OEEC, 1959).

[2] Gilbert and Kravis, op. cit., p. 22, recalculated from *per capita* to per worker; Paige and Bombach, op. cit., p. 21. Taking as 100 the geometric average of American manufacturing value-added per employee in British and American prices, the British level given in Paige and Bombach for 1950 was only 36.5.

[3] Washington, D.C., Brookings Institution, 1967.

[4] Denison, op. cit., p. 332. His findings for the other western European countries studied were much the same.

[5] Denison's theoretical framework is essentially the Cobb-Douglass production function under conditions of equilibrium and perfect competition. A slightly more general framework is that of K. J. Arrow, H. B. Chenery, B. S. Minhas and R. M. Solow in 'Capital-labor substitution and economic efficiency', *Review of Economics and Statistics*, 43, August 1961, pp. 225–50. They, too, find large unexplained differences in productivity between countries, in their case between the United States and Japan.

[6] 'Increasing returns and economic progress', *Economic Journal*, 38, December 1928, pp. 527–42.

[7] 'Causes of the superior efficiency of U.S.A. industry as compared with British Industry', *Economic Journal*, 56, September 1946, pp. 383–90. Recent work on early national income by R. Gallman for the United States and C. H. Feinstein for the United Kingdom suggests that at the par of exchange the income of the two was approximately equal in the 1850s. The argument has the further difficulty that Britain sold to a world market: the market for British cotton textiles, for example, was surely larger than the American market throughout the nineteenth century.

[8] Series 66, p. 141, in U.S. Bureau of the Census, *Historical Statistics of the United States* (Washington, D.C., Govt. Printing Office, 1960) estimates rent as around 8 per cent of American national income from 1870. P. Deane and W. A. Cole in *British Economic Growth 1688-1959* (Cambridge, Cambridge University Press, 1964), p. 247, estimate rent, including apparently some rents of buildings, at around 13 per cent from 1860 to World War I.

[9] The basis for the estimate of a 30 per cent share is the sum of entrepreneurial income and dividends in American national income in the late nineteenth century given in *Historical Statistics* at the place cited above. The reason the share in national income is an upper bound on the relevant share is that, as discussed below, the share relevant to a particular industry's production function would include intermediate goods as well as value-added.

[10] 'The Explanation of Productivity Change', *Review of Economic Studies*, 34, July 1967, 249–84, p. 274. E. Denison has subjected this article to searching criticism, pointing out, among other things, that they did not offer evidence for the assertion quoted here ('Some major issues in productivity analysis: an examination of estimates by Jorgenson and Griliches', *Survey of Current Business*, 49, No. 5, pt II, May 1969, pp. 1–27.

[11] Denison himself admits that he is puzzled by it and remarks that his 'inability to decompose residual productivity or analyze it satisfactorily is surely the greatest gap in the present study' (Denison, op. cit., p. 340).

[12] Cf. E. D. Domar, 'On the measurement of technological change', *Economic Journal*, 71, December 1961, pp. 709–29.

[13] It can be shown, as in Domar, op. cit., that the typical productivity measure is the national measure multiplied by the share of inputs not purchased

from other firms. In the 1947 input-output table for the American economy (given in H. B. Chenery and P. G. Clark, *Interindustry Economics* (New York, Wiley, 1959), p. 222) purchased inputs were 44 per cent of total domestic sales. In the first British Census of Production it was found that 58 per cent of the costs were purchased from other firms (*Final Report on the First Census of Production of the United Kingdom (1907)* (London, H.M.S.O., 1912), p. 19). For a similar group of industries in the American input-output table (excluding, that is, agriculture, fishing, transport, trade and services), 47 per cent were purchased from other firms.

[14] J. H. Clapham, *An Economic History of Modern Britain* (Cambridge, Cambridge University Press, 1938), Vol. III, p. 168.

[15] 'The Coal Industry', chapter 2 in D. Aldcroft (ed.), *The Development of British Industry and Foreign Competition 1875-1914* (London, Allen and Unwin, 1968). p. 69.

[16] Cf. Taylor, op. cit., p. 46.

[17] In anthracite mining output per man-day declined after 1899, while in bituminous it continued to rise (U.S. Geological Survey, *Mineral Resources of the United States 1917* (Washington, D.C., Govt. Printing Office, 1920), pt II, p. 932).

[18] Because the price of any particular ton of coal or man-hour of labour reflects many different quality components, the components would need to be separated by some such method as regressing coal prices on BTUs per ton and other qualities. The analysis should not include costless quality differences in the inputs such as the presence of more vigorous men in America than in Britain; it should include education, experience and other qualities of the inputs requiring investment.

[19] The share of capital and land, calculated as a residual from labour and materials, was 19 per cent in the U.K. in 1919 (*Report of the Coal Industry Commission* (Sankey Commission), SP 1919 XI, p. xii) and 12 per cent in the United States in 1909 (*Census of Mines and Quarries*, pp. 183–229). Assuming that land and capital earned roughly similar returns, these can be split into land and capital by using their shares in total asset values. C. H. Feinstein's data on the coal industry in his *Domestic Capital Formation in the United Kingdom 1920-1939* (Cambridge, Cambridge University Press, 1965, pp. 80 ff) imply that the depreciated value of fixed capital in historical prices plus the value of stocks in trade was £146 million in 1920, while the value of coal deposits and surface land was £96 million. According to D. B. Creamer, S. P. Dobrovolsky and I. Borenstein's *Capital in Manufacturing and Mining* (Princeton, Princeton University Press, 1960, pp. 274 ff.) in the United States in 1909 the value of capital ($486 million) was much smaller in relation to all land used in the industry ($1064 million) than in the United Kingdom. The upshot is that while the estimates of the shares of land in Britain and America are about the same (7.5 and 8.2 per cent), the British share of capital (11.5 per cent) is much higher than the American (3.8 per cent).

[20] Strictly speaking, a conversion of the stock of land into a flow of services from land is required. Jorgenson and Griliches (op. cit.) criticized J. W. Kendrick for aggregating stock of capital rather than service flows and the same point applies to land. The fullness of utilization of coal land may have been different in the two countries, yielding different flows from the same stock.

[21] Incidentally, the pattern of coal land tenure is a good example of the effect

of economic conditions on legal arrangements. In the United Kingdom, apparently, land was expensive enough to overcome the high transaction costs of selling mineral rights and surface rights separately and to warrant more specialization between ownership of the rights and exploitation of the rights (over two-thirds of American coal acreage was owned outright by the mining companies; in Britain, however, ownership of coal by the mines was exceptional).

[22] It might seem reasonable to weight the reserves by the share of the region—the state in America and the county in Britain—in total output. It is not: although this weighting scheme corresponds with what one does unconsciously in assessing the size of actively used coal reserves, it yields a statistic that varies with the degree of detail chosen, as an arithmetic example can make clear. Suppose there were three districts with outputs of 1, 1 and 1 and with reserves of 2, 3 and 4. If the statistic were calculated taking all three districts separately, it would be 9/3. Taking the first and second together, it would be 14/3.

[23] 12th International Geological Congress, *The Coal Resources of the World* (Toronto, Morang 1913), vol. II, article by M. R. Campbell, 'The coal reserves of the United States', pp. 525–39. The definition of the intensity of mining is the ratio of 1909 output to the states' total reserves. The definition and the truncation at six states is highly arbitrary. The implicit assumption is that in these states the exploitation of coal land was as intense per ton of reserves as in Britain. For Pennsylvania and Maryland this is no doubt true. For the others it is less plausible.

[24] To make the comparison with the United States (whose reserves were given for seams greater than 2 ft in thickness at a depth of less than 3000 ft), the British reserves of 171,000 million metric tons (International Geological Congress, op. cit., p. 628, with Scotland's probable reserves estimated on the basis of the ratio of 'probable' to 'actual' in England and Wales) had to be reduced by estimates of the British reserves between 3000 and 4000 ft deep and 1 to 2 ft in thickness (the estimates were 25 per cent of the total to correct for the different standards of depth and 20.7 per cent (given in Colliery Guardian, *Digest of Evidence Given Before the Royal Commission on Coal Supplies (1901-05)* (London, 1905-7), vol. I, p. xxxii) to correct for the different standards of thickness. This procedure entails the assumption that depth and thickness were not correlated. They would be at shallower depths and greater thicknesses because of selective mining of the shallower and thicker seams, but at these far limits of depth and thickness the assumption is reasonable.

[25] See, for example, F. G. Tryon and M. H. Schoenfield, 'Comparison of physical conditions in British and American coal mines', *Coal and Coal Trades Journal* 57, pp. 934, 956–7, 1087–9, 1202–6 (4 parts), autumn weeks of 1926. Tryon was the chief statistical adviser to the United States Coal Commission and was in charge of the U.S. Geological Survey coal statistics. Tryon and Schoenfield use the data on British mines collected for the Royal Commission on the Coal Industry (the Samuel Commission) of 1926. A table, also from the Samuel Commission, on the conditions of coal mining in the major coal-mining countries is reproduced in the League of Nations, International Economic Conference, *Memorandum on Coal* vol. I (Geneva, 1927), p. 39, as well as in Tryon and Schoenfield, op. cit., p. 1203.

[26] This point is made repeatedly in the testimony of the witnesses to the Royal Commission on Coal Supplies (1901-5). See Colliery Guardian, op.

cit., vol. 1, chapter 1, 'The working of thin seams'; chapter II, section 3, 'Evidence as to thickness of seams worked at great depths'.

[27] Errors in the independent variables will also bias the coefficient on thickness in a regression explaining output per man downward. Unfortunately, simultaneous equation bias, of which this is a classic case (because there exists another relation among the variables namely, the conditions of profit maximization), works in the other direction.

[28] Revised ed. (Washington, D.C., Govt. Printing Office, 1891), pp. 199 ff.

[29] Cf. Tryon and Schoenfield, op. cit., p. 1205, speaking of the 1920s: 'In the bituminous mines of the United States, no marked correlation between average thickness and average depth of working has yet developed simply because the readily accessible coals have not been exhausted.'

[30] *Report of the U.S. Coal Commission* (Washington, D.C., Govt. Printing Office, 1925), part II, p. 1079.

[31] Estimated from Tryon and Schoenfield, op. cit., p. 1088. American bituminous seams in 1920 averaged 63 inches and anthracite seams in 1922 80 inches. 1922 was a depressed year in anthracite mining and the figure of 80 inches may therefore be too high: in bad years thin seams were not mined. 1920 and 1924 were prosperous years for coal in the United States and Britain.

[32] Output per man was very uniform in the U.K. compared with the U.S.; cf. Tryon and Schoenfield, op. cit., p. 1204.

[33] Tryon and Schoenfield, op. cit., p. 1205, give the average depth of coal in seams under 2 ft in thickness as 517 ft, between 2 and 4 ft as 876 ft, between 4 and 6 ft as 1163 ft, and over 6 ft as 1351 ft.

[34] Cambridge, Cambridge University Press, 1940.

[35] Burn, op. cit., pp. 303, 213, 11; and Burnham and Hoskins, *Iron and Steel in Britain 1870-1930* (London, Allen and Unwin, 1943), p. 271.

[36] The equivalence of measures of productivity using prices and quantities has received attention recently. See, for example, D. W. Jorgenson, 'The embodiment hypothesis', *Journal of the Political Economy* 74, 1–17, February 1966, p. 3 n. An early use of the price measure, familiar to economic historians, is G. T. Jones, *Increasing Return* (Cambridge, Cambridge University Press, 1933), esp. p. 33 (Jones's index can be shown to be identical to the price measure given in Jorgenson). It should be emphasized that the price measure is not merely an approximation to the quantity measure: with consistent data it is identical to it and is therefore not more volatile or uncertain.

[37] The average value of plates and sheets is given in the American census as $40.00 per long ton (U.S. Bureau of the Census, Vol. X, *Manufactures 1909* (Washington, D.C., Govt. Printing Office, 1913), p. 240). The census gives tonnages, but not values, of plates and sheets by gauge (ibid., p. 238). Assuming that a gauge of 17 or lighter is comparable to the British category of 'sheets', and assuming further that sheets sold at the black plate and sheet price (a high estimate of the true price) of $50.00 per ton (given at p. 240), the heavy plate price can be estimated at $36.10 per ton.

[38] The object was to break the American census value of pig iron used in steelworks and rolling mills ($15.10 per ton; ibid., p. 252) into Bessemer and non-Bessemer prices, comparable to the values reported in the British census. The Census gives tonnages for five types of pig iron; the American Iron and Steel Institute's *Statistical Report for 1913* gives 1909 market prices for pig iron similar to each of the five types; from this information and the average census value it is possible to infer the appropriate census values for the Bessemer type and for the rest.

[39] 1907 was a peak year for British steel output and was not surpassed until 1912. In 1909, the American industry produced about 3 per cent more steel than in the previous peak, but the previous peak was three years before and was surpassed in 1910: the industry had ample time to adjust and was not pressed much beyond its previous peak output until 1910.