Labor Scarcity and the Problem of American Industrial Efficiency in the 1850's

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EUROPEANS have been coming to America and commenting about the nature of American technology for over a century. Despite the evident economic changes in the course of this century, the comments on the differences between American and European technology—or, more properly for the nineteenth century, on the differences between American and British technology—have stayed remarkably constant. The factors noted by a few British visitors of the 1850's, perhaps the first technically qualified foreign group to take a careful look at American manufacturing, still form the backbone of discussion today. Chief among the factors noted is the high cost of American labor, but this explanation of American peculiarities by no means stands alone.[1]

The purpose of this paper is to reexamine the statements of the British visitors of the 1850's and the labor-scarcity explanation of American conditions to see if they can be formulated in terms of modern concepts and if they are supported either by logical inferences or by empirical evidence. As the views of these observers have been amplified and restated by several modern authors, our efforts to reformulate the contemporary comments in modern language need not be based on the antebellum documents alone.

I

Two groups of visiting Englishmen are of interest here. The first group came to see the industrial exhibition in New York in 1853 but

* I would like to thank William Letwin, Paul Samuelson, and Richard Sutch for comments on an earlier draft. The remaining errors are mine.

[1] See John E. Sawyer, "The Social Basis of the American System of Manufacturing," JOURNAL OF ECONOMIC HISTORY, XIV (Dec. 1954), 361-79.

arrived to discover that the exhibition was not ready. They used their time to visit American industrial establishments, and the reports of George Wallis, headmaster of the Government School of Art at Birmingham, and of Joseph Whitworth, one of the most prominent British engineers, were concerned with manufactures and machinery. Shortly thereafter, Whitworth testified to a Select Committee on Small Arms that the American methods used to make small arms were worth further investigation, and in 1854 a committee was sent to the United States to survey American methods and to place orders for £10,000 worth of machinery. The amount they had to spend was limited because some members of Parliament insisted that British manufacturers could satisfy the government's needs.[2]

Both groups of visitors talk extensively of the labor-saving machinery they observed in America. An entirely typical statement, for example, states that "on account of the high price of labour the whole energy of the people [in the United States] is directed to improving and inventing labour-saving machinery."[3] Statements like these are exceedingly problematical. On the one hand they seem to indicate clearly—by their emphasis on discovery and invention—that they are talking of what we now call technological change. On the other hand, by their notice that labor is saved by the employment of machinery, they suggest that they may have been observing shifts in factor proportions within a given technology. As this point is a critical one, it is worth taking a little time to state unambiguously and simply what is meant by "technological change" and "a given technology," terms that were not included in the vocabulary of the British visitors.

The argument can be facilitated by reference to Figure 1. The two axes of the graph represent quantities of capital and labor, and points on the graph represent the amounts of capital and labor used to produce a single unit of output. Let us say that point *A* represents the factor combinations used in America, while point *B* shows the

2 Great Britain, Parliamentary Papers, Vol. XXXVI (*Reports*), 1854, George Wallis, "Special Report on the New York Industrial Exhibition" (hereafter cited as Wallis); *ibid.*, Joseph Whitworth (same title; hereafter cited as Whitworth); *ibid.*, Vol. XVIII (*Reports*), 1854, "Report from the Select Committee on Small Arms" (hereafter, "Report on Small Arms") Qq. 1691, 1919-23; *ibid*, Vol. L (*Reports*), 1854-55, "Report of the Committee on the Machinery of the United States of America" (hereafter "Report on Machinery"), pp. 1-3. These reports are summarized in D. L. Burn, "The Genesis of American Engineering Competition," *Economic History*, Supplement to *Economic Journal*, II (Jan. 1931), 292-311.

3 *Report on Machinery*, p. 1. See also Wallis, pp. 2-3; Whitworth, p. 41.

factor combinations used in Great Britain. It will be seen that in America less labor is used to produce a single unit of output than in Britain, and that the machinery used in America consequently may be spoken of as "labor-saving." If the American machines were not known in Britain or had been newly discovered in America, then there would be ample cause for British visitors to the United States to make statements such as the one quoted above.

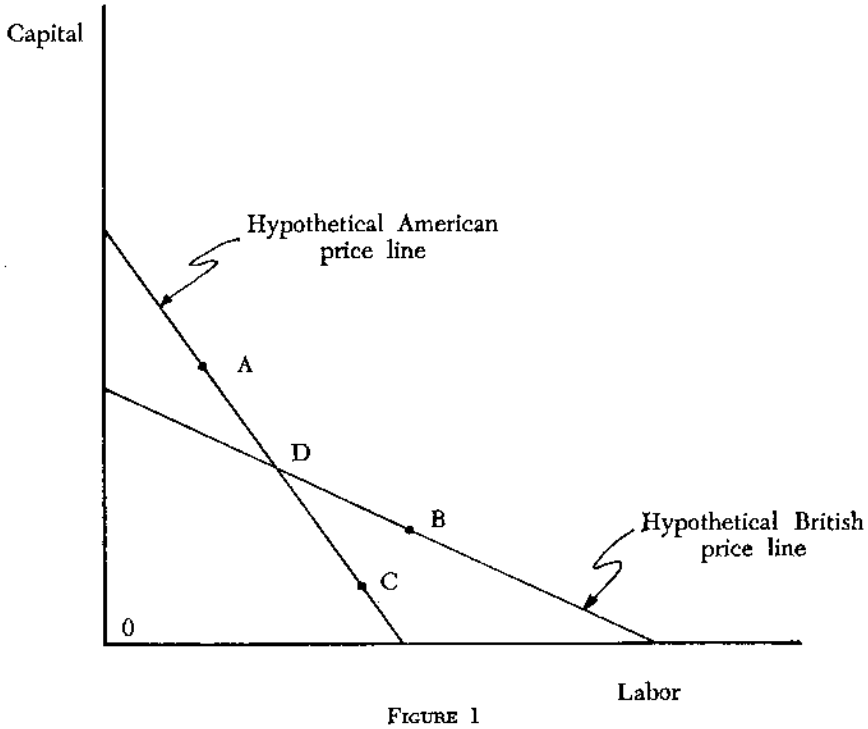

FIGURE 1

Nevertheless, the situation shown in Figure 1 may not represent a difference of technology in the economist's sense. A given technology, in this sense, is a functional relationship showing for any factor prices the cheapest way to produce a given output. In order to show that the two countries were using different technologies in this sense —as opposed to the sense in which the observation of different machines provides sufficient proof—it is necessary to demonstrate that it would have been advantageous for manufacturers in one country to use the methods of the other country in preference to their own, even though their factor prices were different than in the other country. Hypothetical price lines (that is, lines showing the rates at

which capital and labor could be exchanged for each other within each country) have been drawn through the points showing the factor usage in the two countries. The American price line is composed of points showing the amount of labor and capital that could be used in America to produce one unit of output at the same cost as the labor and capital represented by point *A*. Points between the price line and the origin, *O*, show cheaper factor combinations than *A*; points on the other side of the line show more expensive factor combinations. The British price line, similarly, is the locus of points showing factor combinations that would cost *in Britain* the same as the factors represented by point *B*. The line for the United States is the steeper of the two, reflecting the common assumption that labor was more expensive in the United States than in Britain.

It is clear that neither country has an incentive to adopt the practice of the other under the conditions shown. If the British were to use the American factor combinations—with British prices—it would be more expensive than their original factor combinations. Only points within the triangle bounded by the axes and the British price line passing through *B* represent factor combinations as cheap or cheaper than *B* in British prices. As *A* lies outside this triangle, it would be more expensive. Similarly, as *B* lies outside the triangle formed by the axes and the United States price line through *A*, it would be more expensive for Americans to use the British factor combinations than their own.

In general, if the price lines for the two countries drawn through their respective points cross between these points—as at *D*—then there are no grounds for saying that the levels of technology in the economist's sense differ.[4] On the other hand, if the intersection of the price lines lies to one side of both points, then one country is using a more advanced technology than the other. If the United States were producing at point *C*, for example, it could be said that America was using a more advanced technology. This would be so be-

[4] If we knew the isoquants in the two countries—that is, the locus of different factor combinations that produced the same output—we could make a much stronger statement. We could then say whether either country had an incentive to use the *technology* of the other at the factor prices most favorable to it. Normally, however, we do not know the full isoquants. We know only those points at which production was carried on, and we can talk only of the incentives in each country to use the *actual factor combinations* of the other. In the case illustrated by points *A* and *B*, there is no incentive for either country to adopt the practice of the other, and we do not know if the technology of either country provided unexploited opportunities for the other.

cause it would be advantageous for the British to use the American factor combinations even with British prices—that is, *C* lies within the triangle formed by the axes and the price line through *B*.

To discover the location of the intersection of the two price lines it is normally necessary to know with some precision the relative prices and the quantities of the factors used in the two countries. Only if production in one country were carried on using less of both factors per unit of output than in the other could a conclusion be reached without these data. (This would be the case if America produced at *C* while Britain produced at *B*, since *B* is both above and to the right of *C*.) We cannot assume that this was the case in the 1850's. The British visitors talked of labor-saving machinery, implying that the output per man in America was larger than in England, but they did not inform us of the costs of the machines used to achieve this result. (In terms of Figure 1, they said that *A* was to the left of *B*, without specifying whether it was also above or below a price line, representing British prices, through *B*.)

Since we lack precise data, we do not know whether the contrast between American and British practice at the middle of the nineteenth century represented two observations from the same technology or examples of two different technologies. *A fortiori*, we cannot say that the *technology*—as opposed to factor proportions within the same technology—was more labor-saving in America than in Britain. All this is important, because the explanation of American conditions will vary according to what we decide these conditions were. We have a well-developed theory to explain differences in factor proportions within a given technology; we have almost no theory to explain the development of different technologies.

Unfortunately, this ambiguity is only the first of several difficulties with the reports of the English visitors. The reports contain casual observations about many industries, but the British visitors to the United States drew most of their evidence about labor-saving machinery from two rather specific areas. First, they commented on various woodworking industries: musket stocks, furniture, doors and sashes, the wooden parts of agricultural implements.[5] These observations on woodworking were not intended to be applied indiscriminately to other branches of manufacturing, as is shown by the many references to establishments using methods the same as or inferior

[5] Whitworth, pp. 13-14; *Report on Machinery*, pp. 20, 64.

to British ones. In addition, Whitworth stated this explicitly in response to a question from the Select Committee on Small Arms: "Altogether in America, you were more struck with the mode of working the wood than their mode of working the iron?—Much more; they are not equal to us in the working of iron."[6]

The British surprise at American woodworking skill is well illustrated by the attention given to the machinery used to make musket *stocks* at the Springfield armory. This was so spectacular that it was the only machinery that the Committee on American Manufactures ordered without comparing alternate uses for their limited funds.[7] Yet there are at least three difficulties with this story, all of which militate against uncritical generalization from it. First, no one seems to have done careful calculations on the savings to be realized from this machinery. Whitworth was the first to give it prominence when he stated that with its help a man could make a musket stock in 22 minutes, 4.25 seconds. Under questioning, however, Whitworth admitted that this time came from a special trial and that the average working time was probably twice as long. In addition, he admitted that he did not know how expensive the machinery was, although he thought it was no cheaper than £5,000.[8] British enthusiasm for these machines, therefore, was based on something other than considerations of total costs. It might have been based on the novelty of the machinery except for the other two difficulties with the story, which are that Brunel and Maudsley had introduced similar machinery in Britain almost half a century previously and that Blanshard's machine—the key machine in the American process—had been used "very extensively" for thirty years prior to the English visits. The American machines did not represent the latest technological developments, and British enthusiasm for them remains a mystery. Whitworth commented that the American machines had been used much more widely than the British, but he does not tell us whether this was the result of different technologies or—an equally likely possibility—the result of the greater American dependence on wood as opposed to the English use of iron.[9]

[6] Wallis, p. 23; Whitworth, p. 8; John Wilson, *Special Report on the New York Industrial Exhibition*, British Parliamentary Papers, 1854, XXXVI, pp. 100-1; *Report on Machinery*, pp. 12, 13, 19, 20, 33; *Report on Small Arms*, Q. 2043.

[7] *Report on Machinery*, p. ii.

[8] Whitworth, p. 26; *Report on Small Arms*, Qq. 1979, 2137. Whitworth's estimate of the cost of the machinery—16 machines—was of the right order of magnitude, although not much better than that. The Committee on American machinery paid $30,000 for a set, or about £6,250; *Report on Machinery*, p. 75.

[9] Whitworth, p. 13; *Report on Machinery*, p. 38; Wilson, pp. 100-1; Joseph Wick-

The second group of industries noticed by the English visitors was composed of several branches of hardware and ordnance manufacture: wood screws, locks, clocks, and small arms.[10] These industries all produced light, highly fabricated products made on a standardized basis and, if they had parts, with interchangeable parts. The introduction of machinery in this group of industries cannot be separated from the standardization of products and parts. As one recent writer, H. J. Habakkuk, noted at the outset of his discussion, this innovation may have been the result of the "particular ability of Whitney and North." Habakkuk went on to assert that the American developments were too general for such a particular explanation to cover them, but to the extent that the British visitors concentrated on this small group of industries, their evidence supports the view that Habakkuk rejected.[11]

While these two groups of industries provided the source for the bulk of the British visitors' evidence, American progress in other industries was also noted. Some of these examples cannot be taken seriously—such as Whitworth's comparison of spinning productivity in the United States with that in "Hindoostan"—but many must be. Examples of the latter class include Burn's triad of American innovations being introduced in England at this time: the sewing machine, the mechanical reaper, and the Corliss steam engine.[12] Nevertheless, the lack of evidence about whole areas of American industry and the known American backwardness in the production and fabrication of iron indicate that the following hypothesis cannot now be rejected: that the American and British economies at the middle of the nineteenth century were using essentially the same technology.[13] Technology here is used in the sense defined above; it does

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ham Roe, *English and American Toolbuilders* (New York: McGraw-Hill, 1926), ch. iii.

[10] Whitworth, p. 11; *Report on Machinery*, pp. 20, 32, 69, 70; Burn, pp. 294-95.

[11] H. J. Habakkuk, *American and British Technology in the Nineteenth Century* (Cambridge, Engl.: The University Press, 1962), pp. 5, 95. Whitney's name should probably be replaced by John Hall's in this context. See Robert S. Woodbury, "The Legend of Eli Whitney and Interchangeable Parts," *Technology and Culture*, I (Summer 1960), 235-53.

[12] Whitworth, p. 42; Burn, pp. 297-301.

[13] For iron, see Peter Temin, *Iron and Steel in Nineteenth-Century America* (Cambridge: M.I.T. Press, 1964). Difficulties of evidence in other areas may be illustrated by the example of flour milling. Habakkuk (p. 93) followed other investigators in stating that the primary importance of Oliver Evans' innovations was in their reduction of labor requirements. Yet Evans himself calculated that only 10 per cent of the savings came from this source, and the actual savings are not known. See Greville and Dorothy Bathe, *Oliver Evans: A Chronicle of Early American Engineering* (Philadelphia: Historical Society of Pennsylvania, 1935), p. 168.

not mean the same machines or the same factor proportions, and the differences between American and British practice still remain to be explored. The word "essentially" is introduced to allow for occasional differences between the countries that could arise from lags in the communication across the Atlantic of new innovations which could originate in either country. This hypothesis should not be regarded as confirmed by the data; but if the data do not conflict with a representation of reality by a known theoretical scheme, there is little incentive to suppose the contrary and incur the necessity of formulating new theory.

Turning to an explanation of the still inadequately delimited Anglo-American differences, we find that the British visitors of the 1850's had four different explanations: (1) the scarcity of labor in the United States; (2) the extent of the American market (and the introduction of railroads, according to Whitworth); (3) the energy of the American people; and (4) the education of the American workman.[14] The first of these has been repeated and amplified most often and we concentrate on it.

II

The modern discussion of the effects of labor scarcity in America may be said to have started with the posthumous article of Erwin Rothbarth. Rothbarth argued that wages were high in the United States due to the availability of inexpensive land. In order for industry to attract labor, the marginal product in industry had to be large enough to justify paying the wage established in agriculture. This was accomplished, Rothbarth argued, by the installation of labor-saving machinery.[15]

Unfortunately, Rothbarth did not spell out his argument, and we shall have to do so for him. The argument was cast in terms of the traditional three factors of production: land, labor, and capital. Land was plentiful in America, allowing for the use of large amounts of land per worker and resulting in high wages. As nothing was said about the effects of the plentiful land on the interest rate (that is, the price of capital), we must assume that Rothbarth was dealing

[14] These themes are interwoven throughout the primary documents, but see particularly Wallis, pp. 2-4, 68; Whitworth, pp. 5, 41-42; *Report on Machinery*, pp. 32, 38.

[15] E. Rothbarth, "Causes of the Superior Efficiency of U.S.A. Industry as Compared with British Industry," *Economic Journal*, LVI (Sept. 1946), 383-90.

with a model in which agriculture used no capital. When Rothbarth turned to manufacturing, only labor and capital were mentioned—the latter in the form of labor-saving machines—and we assume also that land was not used to produce manufactured goods. The underlying model, in short, is one in which agricultural goods were produced by land and labor alone, while manufactured goods were produced by labor and capital alone. Despite its obvious shortcomings, this model appears to be implicit in all discussions of this problem. (The argument to be presented here remains valid if capital was used in agriculture. On the other hand, it would require substantial modification if land was used in manufacturing.)

Although Rothbarth talked of three factors, he specified the price of only two: land was cheap, and labor was dear. What was the cost of capital? Since Rothbarth did not answer this question, he could not say whether the use of labor-saving machinery in the United States was the result of factor substitution within the same technology as was being used in Britain, or whether it represented a different—and presumably superior—technology. I shall argue that only if the interest rate were lower in the United States than in Britain would there have been an incentive for Americans using the same technology as Englishmen to substitute capital for labor in manufacturing. As the interest rate was in fact higher in the United States than in Britain, Rothbarth's argument must be interpreted as an argument for technological change. The argument will be given verbally in the text; mathematical proofs of the important propositions are presented in an appendix.

Rothbarth's ideas have been greatly expanded by H. J. Habakkuk, and it is useful to consider the labor-scarcity argument in the context of his fuller treatment. Habakkuk dealt both with factor substitution within a given technology and with technological change, on the basis that the high cost of labor in America was an inducement for both activities. Nevertheless, when he came to summarize his argument "with the aid of rather extreme assumptions made for the purpose of exposition," Habakkuk spoke only of factor substitution, and we may begin our argument with this summary:

> It is possible with a small number of assumptions to explain why dearness of labour should have given American investment a capital-intensive bias. Suppose that labour was 30 per cent dearer in the U.S.A. than in England, that is, that there was a reservoir of agricultural labour in both countries from which industry could draw additional labour at a going wage, but the going wage was

30 per cent higher in the U.S.A. because land was plentiful and productive, and because labour, while moving freely within the U.S.A. and within England, did not move between them sufficiently to remove the disparity. Suppose also that product-prices in the U.S.A. were higher than in England by sufficient to ensure the same level of profits in both countries, that is, that the tariff was high enough to offset the net effect on profits of dear American labour. If in this situation the prices of capital goods and interest rates were the same in both countries and unchanging, the Americans would adopt more capital-intensive techniques than the English.[16]

It is useful to examine this summary statement by first ignoring the last sentence. As the summary appears to refer to nonagricultural investment, we may also exclude agriculture temporarily from the discussion. Since the underlying model says that land was used only in agriculture, we have excluded it also and need to treat only two factors: labor and capital.

Habakkuk's argument then starts with two assumptions, only one of which is given explicitly in the summary quoted. First, money wages in the United States were 30 per cent higher than in Britain. Second, technology in the two countries was the same. The first assumption is derived from the effect of agriculture; the labor-scarcity argument is designed to show its implications. The second assumption is required in order to show these implications. If the second assumption were not made, then any differences between American and British practice could have come either from the different wage or from the difference between the two technologies—a difference that could easily have been independent of the cost of labor. (If a difference in technology is *assumed*, then the argument says nothing about its cause.) If the argument is to show that the cost of labor led to the differences between the United States and Britain, then it must show how in two economies that were identical except for the cost of labor, differences similar to antebellum Anglo-American differences would arise.

If the price level in the United States was *less* than 30 per cent higher than in England, the rate of profit (or equivalently the return on capital or the interest rate) must have been lower. To show this, assume the contrary: that real wages were higher in the United States than in England while the return to capital was no lower. Since the technologies of the two countries are assumed to be the same, the higher wage in the United States must have been due to

[16] Habakkuk, p. 76.

a higher capital-labor ratio than in England. If so, then the return to capital should have been lower as a result of the normal convexity of production functions. If the return was not lower, then the rise in the real wage was "costless" in the sense that it did not require an offsetting decline in the interest rate, and the British should have been taking advantage of this fact. In other words, producers in England either were not behaving rationally or they were using a different and less good technology than producers in the United States. Since neither of these possibilities is tenable—the first because it denies the usefulness of this form of reasoning and the second because it amounts to an assumption of the desired conclusion—prices must have been 30 per cent higher in the United States than in England for wages to have been 30 per cent higher and interest rates the same. Consequently real wages in the two countries were the same; the difference in wages is a statistical illusion caused by using the exchange rate to compare wages, rather than the exchange rate plus the tariff—which Habakkuk introduced into his model precisely in order to destroy the significance of the exchange rate—or the purchasing power of the different currencies.

This argument can be restated in terms of the factor-price frontier. This frontier shows the maximum real wage that can be obtained within a given technology for any given interest rate. Its general shape is shown in Figure 2, which we may use to represent the factor-price frontier using British technology. It slopes downward because in order to increase the real wage—say from W_1 to W_2—it is necessary to decrease the interest rate, in the case shown, from i_1 to i_2. If it were not necessary for the interest rate to fall, the point (W_1, i_1) would not be on the frontier, since W_1 would not be the maximum real wage consistent with interest rate i_1. The argument just stated simply says that if the interest rate and the technology in America and Britain were the same, then both countries were at the same point on the same factor-price frontier and the real wage—the ratio of money wages to the price of goods—was consequently the same too. (For the real wage, in terms of industrial goods, to have been higher in America, either the interest rate must have been lower or there must have been a different technology in America.)

Now consider the last sentence of Habakkuk's statement. In this sentence he assumed that the price of capital goods in the two countries was the same—that is, that in terms of the wage rate, machines were cheaper in the United States than in England. If this were true,

Americans would have used more machines per worker than the British, since the cost of doing so (the price of machines times the interest rate) would have been lower relative to the wage rate. But under what conditions would this be true? The preceding argument has shown that if the interest rate were the same in the two countries, prices in the United States would have been as high relative to British prices as American wages were to British wages. The price

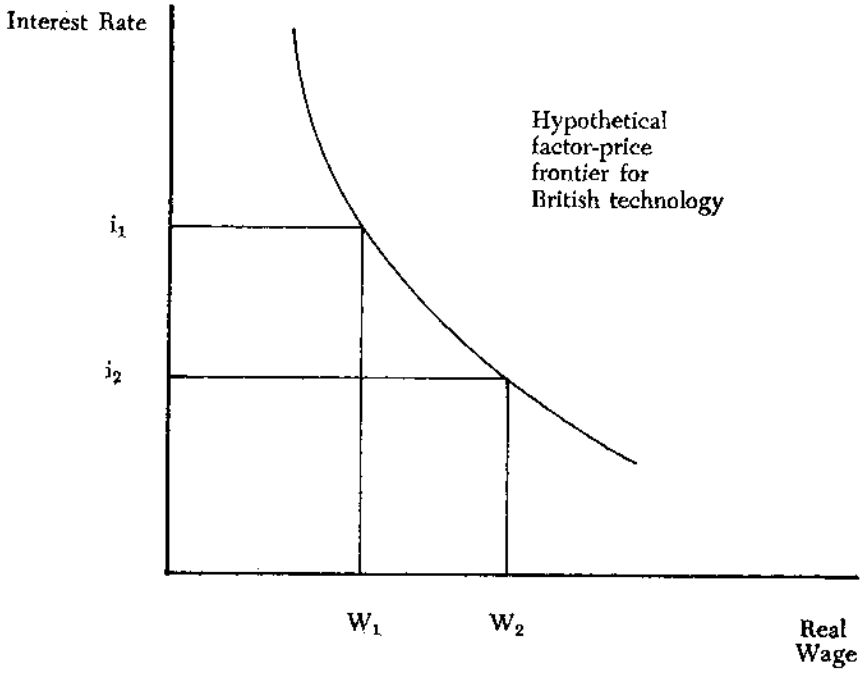

FIGURE 2

of machines in America would then have been as expensive relative to the wage rate as in Britain.

In fact, it is a general proposition that if labor is used to build machines, then in two economies with the same interest rate machines will have the same price relative to wages (still assuming, of course, the same technology). Only if the interest rate changes will the relationship of machinery prices to other prices vary. One way to see this is to assume that an economy is in long-run, static equilibrium. Then let there be a rise in the money wage. The price of existing machines will not have changed, and there will be a substitution of these machines for the now more expensive labor, producing a rise in the *real* wage. However, labor is used to make machines, and

the price of new machines will rise as a result of the rise in the wage rate. As the price of machines rises, the ratio of machines to labor used in production will fall, causing the real wage to fall with it. This process will continue until the price of machines has risen exactly as much as the money wage rate and until real wage rates have returned to their original level—that is, until the economy returns to the point on the factor-price frontier corresponding to the unchanged interest rate. Only at this point will a new long-run equilibrium be attained.[17]

Habakkuk stated specifically that the interest rates in the two economies he was considering were equal, and he consequently could not explain a difference in capital-intensity in the two economies by adjustments to different wage rates. As has just been shown, the supposition of different wage rates is a purely monetary matter, the real wage rate in both hypothetical economies being the same. Habakkuk treated this problem at an earlier point in his argument where he said,

> It does not seem essential that the cost of finance in industry should have been lower, in relation to labor-costs, in the U.S.A. than in Britain. It is enough if machines were cheaper in America in relation to labor, either because they could be imported or because they were made with the type of labor that was relatively most abundant.[18]

This statement presents a choice of two assumptions to circumvent the problem created by the supposition of the same interest rate—the same "cost of finance"—in the two countries. Neither of these assumptions, however, is acceptable. The importation of machinery from Britain is irrelevant, as the purpose of the argument is to explain the use in America of *American* machines.[19] (In addition, such importation would have been possible only if the tariff that allowed profits to be as high in the United States as in Britain did not extend

[17] The appendix contains a proof that the equilibrium capital-labor ratio does not depend on the money wage rate. See Paul A. Samuelson, "A New Theorem on Non-Substitution," in *Money Growth and Methodology*, published in honor of Johan Akerman (Lund, Sweden: Gleerup, 1961), for a summary of the relevant literature. Habakkuk (p. 8) showed that he was aware of this problem: "If it paid American entrepreneurs to replace expensive American labour by machines made by expensive American labour, why did it not pay English entrepreneurs to replace the cheaper English labour by machines made with that cheaper labour?" His efforts to deal with it will be analyzed next.

[18] Habakkuk, p. 26; see also p. 18 for another statement of the importation argument.

[19] This is evident in any of the primary sources and was recognized by Habakkuk at the outset of his discussion (p. 5).

to machines.) The introduction of two distinct kinds of labor is no more satisfactory, both because the hypothesized difference in wage differentials in the two countries is neither obvious nor documented and because the use of two kinds of labor is in conflict with the simple two-factor model—labor and capital—used in the summary quoted here and throughout much of the rest of the argument.[20] The scarcity of labor therefore cannot explain why Americans used more (American) machines per worker than the British if there was no difference between American and British technology.

Now let us bring agriculture back into the argument. It is clear that the real wage referred to in the preceding discussion is the ratio of money wages to the price of *industrial* goods. As agriculture had been omitted from the discussion, no statements have been made about agricultural prices. This is entirely proper, as in a given technology the level of profits within the industrial sector is a function only of the ratio of wages paid in that sector to the prices of its products. In other words, with the same interest rate in both countries, the ratio of money wages to the price of machines and to the price of other industrial goods would have been the same in both countries. But if land was plentiful, the ratio of any of these to the price of food would have been higher in America. The argument given here thus does not deny that the availability of productive land raised real incomes—now computed as a ratio of money income to *all* prices—in America.

The preceding discussion has assumed equal interest rates in Britain and America. What if they were different? It was stated above that the price of machines would rise with the wage rate if the interest rate were constant. The cost of using machines is equal to the interest rate times the price of the machine, and this cost would not have risen relative to the wage rate. If the interest rate rose, even if the price of machines did not rise relative to the wage rate, the cost of using a machine would rise. The price of machines would be no greater relative to the wage rate, but the product of this price and the now-higher interest rate would be. Consequently, in two countries that used the same technology but had different interest rates, the one with the higher interest rate would use the less capital-intensive production processes.

[20] A third possible way to validate the stated argument would be to assume some kind of technological change in the production of machines. As this would be an assumption of the conclusion, it is hardly a satisfactory solution.

The interest rate in the United States was consistently *higher* than the rate in Britain during the first half of the nineteenth century.[21] Consequently, had the two countries been using the same technology, the United States should have used *less* machinery than Britain. It is possible, in other words, that the United States was not a labor-scarce, but a capital-scarce economy! In this case, the hypothetical points and price lines of Figure 1 need to be relabeled and the empirical evidence reexamined. (Evidence can be found to support the existence of capital scarcity, primarily in the widely noted flimsiness of American machines, but care must be used in the application of the theoretical argument. Examples have been found where a high interest rate is an inducement to use *more* machines, and we cannot be sure that we have avoided such a possibility.)[22]

To summarize, the availability of land in the United States cannot be used as an argument for a more labor-intensive use of the manufacturing technology being used in Britain. A lower interest rate in the United States would be needed to explain such a phenomenon, and such a lower interest rate did not exist. If the Americans were using more capital per worker than the British, it must have been due to their use of a different technology. But why would they invent such a technology?

If the factor-substitution interpretation of the labor-scarcity argument is not tenable, it must be interpreted to mean that the Americans were forced to invent a new technology by the greater availability of land in America than in Britain. To rephrase this argument, it asserts that the comparative advantage of the United States in agriculture—using British technology—was so great that under conditions of free trade and without changing the technology, the United States would have completely specialized in agriculture. To avoid this, the Americans were forced to create a new technology. (It is assumed, of course, that the invention of a new technology was a process that used resources. Otherwise the discovery of new technologies would have been costless, and everyone would

[21] Sidney Homer, *A History of Interest Rates* (New Brunswick, N. J.: Rutgers University Press, 1963), pp. 195-96, 286-87.

[22] Habakkuk noted both the flimsiness of American capital (pp. 85-89) and the theoretical problem (pp. 19-21). More empirical evidence that conflicts with the view of the British visitors is also available. For example, Abram Hewitt, visiting Britain from the United States in 1867, wrote back that "the new rolling mills beat us to death by the use of hydraulic cranes everywhere to lift and carry the iron. They do not employ half the men we do for the same work"; quoted in Allan Nevins, *Abram S. Hewitt* (New York: Harper, 1935), p. 246.

have discovered them.) We consider these two propositions in turn. Was the invention of a new technology a *necessary result* of American comparative advantage in agriculture?

First, the statement that land was more abundant in the United States does not, by itself, demonstrate that manufacturing could not have existed in the United States using British technology or that labor was more expensive in the United States. If the difference between the factor proportions in the two countries were relatively small—a concept that acquires meaning only in the context of known production functions—then under conditions of free trade and no transportation costs, both countries could have produced the same line of goods, although the share of any one good in the total output would have differed. In this case, factor prices in the two countries would have been the same; the greater availability of land in America would not have resulted in a higher wage rate.[23] This possibility, which does not seem highly probable to the casual observer, should be tested before it is dismissed.[24]

Even if manufacturing was not possible in America under free trade, the Americans were still not forced to invent new production methods. For example, they might have instituted tariffs to protect their manufactures. If these tariffs were high enough to end all trade between America and Britain, then conditions in the United States could be analyzed in isolation. The conclusions would be exactly the same as those already derived in the discussion of Habakkuk's summary, namely that manufacturing was possible in the United States without the use of either a new technology or labor-saving machinery (if the interest rate in the United States were not lower than in Britain). It is entirely possible that the American tariffs of the early nineteenth century were high enough to make this discussion relevant to a great number of industries.[25]

[23] This is the well-known factor-price equalization theorem; see Paul A. Samuelson, "Prices of Factors and Goods in General Equilibrium," *Review of Economic Studies*, XXI, No. 1 (1953), 1-20.

[24] Several estimates of real per capita incomes in Britain and the United States fail to show higher incomes in America; see Robert Gallman, "Gross National Product in the United States, 1834-1909" (paper delivered to the Conference on Research in Income and Wealth, Chapel Hill, Sept. 1963). Data on the costs of farms, collected to refute the "safety-valve" thesis, are consistent with this discounting of abundant land; see Clarence Danhof, "Farm-Making Costs and the 'Safety Valve': 1815-1860," *Journal of Political Economy*, XLIX (June 1941), 317-59.

[25] How high would such a tariff have to be? If the interest rates in the two countries were the same, the tariff would have to be enough to raise the price of manufactured goods as much as the money wage rate in America exceeded the

Finally, even if there was much more land in the United States than in Britain and if tariffs were not high enough to permit manufacturing with British technology, the Americans could have chosen to concentrate exclusively on agriculture. To say that an activity is needed to achieve a goal is not to say it is necessary, unless you can also show that the goal was necessary. To enter manufacturing would have been a *choice* by Americans even in this situation—since agriculture in America was prosperous—and the reasons for this hypothetical choice have not been explored. At the present stage of knowledge, therefore, we cannot say that they included the scarcity of labor.

One question remains in this discussion of labor scarcity. If there was American innovation, Habakkuk asserted that it was labor-saving.[26] Unless the interest rate were lower in the United States than in Britain, there would have been no incentive to adopt existing labor-saving machines. What incentive was there then to invent new labor-saving machines as opposed to new machines that "saved" both labor and capital?

Habakkuk's argument on the nature of the new technology is not amenable to simple summary, but several of his arguments seem to indicate that inducements to invent labor-saving techniques were found in the new technology itself. For example, he asserted that "technical possibilities were richest at the capital-intensive end of the spectrum," and that "inventions which save labour are likely to be more widely applicable, or to suggest possibilities of new methods over a wider range of processes than are those which save specific raw materials."[27] If this is a correct interpretation of his argument, it raises two further questions. First, what evidence do we have for the asymmetric opportunities in technological development? And second, why were these opportunities not as inviting in England as in the United States? Neither of these has yet been answered.[28]

money wage rate in Britain. In this case the relative factor prices *in manufacturing* would be the same in both countries, and the manufacturing sector in the United States would be a smaller replica of the one in Britain. With different interest rates, the problem becomes more complex, and different rates would be required on different goods, the exact rates for different industries depending on the capital-intensity of production.

[26] Habakkuk, p. 9.

[27] Habakkuk, pp. 50, 159.

[28] For theoretical analyses of the inducements to seek labor-saving or capital-saving innovations when the search for new methods of production is viewed as an

III

The other explanations used by the British visitors of the 1850's may be dealt with quickly. The size of the American market will not serve as an explanation of American superiority over Britain, as the American market was smaller than the British. True, the country was larger, but this only meant that the approximately equal population was spread out over a larger area. Consequently, the market in which any single manufacturer could sell for a given transportation cost was smaller in the United States than in Britain.[29] The use of American education and energy is no more satisfactory. Americans were more often literate than Englishmen, and they did appear to travelers to be energetic. Nevertheless, the economic importance of these characteristics is not clear. We do not doubt that education and energy are desirable, but an explanation of American technical progress needs to be more complete than this.

For example, a theory that would incorporate American education and energy would probably assert the importance of communication. Education would have increased the ability of Americans to keep abreast of technical developments elsewhere; energy would presumably have increased their desire to do so. (The British visitors commented that American workmen kept themselves informed about new methods of production, both in England and America.)[30] If the two countries started from a common technological base, the American ability to learn from others more than others could learn from America might have led to a divergence of technologies at a later time.

This speculation may be joined with the hypothesis introduced earlier to form an expanded version of this hypothesis, which may now be stated and left to be tested by future investigators: For much of the first half of the nineteenth century, it would appear that the Americans and the British employed essentially the same technology in their industrial production. Inventions were being made spontaneously in both countries, and there were minor differ-

investment—that is, when various types of technological change are assumed to be produced at a known cost—see Morton I. Kamien and Nancy L. Schwartz, "Optimal 'Induced' Technical Change" (paper presented to the Conference on the Microeconomics of Technological Change, Philadelphia, Mar. 1966) and Paul A. Samuelson, "A Theory of Induced Innovation Along Kennedy-Weizsäcker Lines," *Review of Economics and Statistics*, XLVII (Nov. 1965), 343-56.

[29] This argument is due to Rothbarth.

[30] Wallis, pp. 5, 67-68; *Report on Machinery*, p. 38.

ences in the technologies of the two countries as a result of delays in communication. As the Americans seem to have been more interested in British discoveries than the British were in American developments, an asymmetry in the flow of information may be postulated. This asymmetry gradually led to a divergence of the two technologies, with that of America in the van. But even within the common technology, there were differences of practice. The most important and persuasive of these was the use of *less* capital per worker in America as a result of the higher interest rate in that country, a phenomenon widely noted in the form of flimsy capital equipment and rapid depreciation. The scarcity of labor and the extent of the market in America may be dismissed as statistical illusions: the first arising from a preoccupation with money wage rates and a neglect of capital costs; the second, from a confusion between the geographical and the "economic" extent of the market. The reputed effects of the energy and education of the American workman can neither be confirmed nor refuted at this point. We do not know whether they are necessary to explain the not-very-precise data; nor do we know the mechanism by which they are thought to have affected the level of technology.

Finally, it must be emphasized that this argument is not presented as a substitute for empirical investigation. It is necessary to preserve coherence in theoretical discussions, but theoretical discussions can do no more than separate the myriad internally consistent possible explanations of phenomena from their logically invalid cousins. The selection of appropriate explanations from the former class cannot be done by theory alone.

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MATHEMATICAL APPENDIX

Consider a competitive economy where two types of goods—agricultural (A) and manufactured (M)—are made by three factors of production—land (T), labor (L), and capital (K)—using the following production functions:

$$Q_A = f(L,T) \tag{1}$$

$$Q_M = g(L,K). \tag{2}$$

Both functions are assumed to be homogeneous of degree one, to have positive first derivatives and negative "own" second derivatives. In other words, there are no economics or diseconomics of scale, factors of production are never redundant, and there are diminishing returns to any single factor.

As a result of the homogeneity assumption we may rewrite equations (1) and (2) as:

$$Q_A = L \cdot f\left(1, \frac{T}{L}\right) = L \cdot F\left(\frac{T}{L}\right) = L \cdot F(t) \tag{3}$$

$$Q_M = L \cdot g\left(1, \frac{K}{L}\right) = L \cdot G\left(\frac{K}{L}\right) = L \cdot G(k), \tag{4}$$

where $t = \frac{T}{L}$ and $k = \frac{K}{L}$. The new functions, $F(t) = f(1,t)$ and $G(k) = g(1,k)$, are simply different ways of expressing the relations in equations (1) and (2). Accordingly, they have positive first derivatives and negative second derivatives. For example:

$$G'(k) = \frac{dg(1,k)}{dk} = \frac{1}{L} \frac{\partial g(L,K)}{\partial K} \frac{dK}{dk} = \frac{\partial g(L,K)}{\partial K} > 0 \tag{5}$$

In this economy, land is not used to produce manufactures and capital is not used to produce agricultural goods. In addition, there are no separate capital goods, and manufactured goods may be used interchangeably for capital and consumption. That is, the model recognizes the existence of only one manufactured good which can be used as capital or consumed. The gross rental of capital goods, r, will be equal to the marginal revenue product of capital:

$$r = P_M \frac{\partial g(L,K)}{\partial K} = P_M G'(k) \tag{6}$$

Assume there is no depreciation. Then the interest rate, *i*, equals the gross rental rate of capital goods divided by their price, P_M, which is simply the price of manufactured goods:

$$i = \frac{r}{P_M} = G'(k). \tag{7}$$

The interest rate is thus a function of the capital-labor ratio in manufacturing. As a result of our assumptions about $G(k) = g(1,k)$, we can solve equation (7) for *k* to get its inverse. In other words, the direction of causation can go in either direction. Given the capital-labor ratio, the interest rate is then determined. Alternatively, if the interest rate is fixed, the capital-labor ratio is also. It is clear that changes in the wage rate will not affect the capital-labor ratio as long as the interest rate stays constant. This is the theorem underlying the discussion of the text.

It is clear that this result does not depend on the nature of the agricultural production function. The argument used only the manufacturing production function, and it is valid whatever the form of the production function in agriculture. Specifically, if capital was used in agriculture, the result would be unaltered. A change of assumptions such as this would be important for any general equilibrium model, but it is immaterial for the partial equilibrium argument given here.

The model can be generalized to admit more than one manufactured good. For example, let there be consumption goods, denoted by subscript 1, and capital goods, denoted by subscript 2. The rental rate of capital goods will equal their marginal revenue product in the production of both goods:

$$r_1 = P_1 G_1'(k_1) \tag{8}$$

$$r_2 = P_2 G_2'(k_2). \tag{9}$$

The interest rate equals the ratio of the rental rate to the price of machines:

$$i = \frac{r_2}{P_2} = G_2'(k_2) \tag{10}$$

$$i = \frac{r_1}{P_2} = \frac{r_1}{P_1} \cdot \frac{P_1}{P_2} = G_1'(k_1) \frac{P_1}{P_2}. \tag{11}$$

Accordingly, if the interest rate is determined outside the system, k_2 is determined also. We now inquire about k_1.

Wages in both industries will be equal to the marginal revenue product of labor:

$$w_1 = P_1 \frac{\partial Q_1}{\partial L} = P_1(G_1(k_1) - k_1 G_1'(k_1)) \tag{12}$$

$$w_2 = P_2 \frac{\partial Q_2}{\partial L} = P_2(G_2(k_2) - k_2 G_2'(k_2)) \tag{13}$$

If both goods are produced, $w_1 = w_2$ as a result of the competition for labor between the two industries. In this case, we can equate equation (12) to equation (13) to get:

$$\frac{P_1}{P_2} = \frac{G_2(k_2) - k_2 G_2'(k_2)}{G_1(k_1) - k_1 G_1'(k_1)} = H(k_1,k_2), \tag{14}$$

where $H(k_1,k_2)$ is just the expression between the two equal signs. We may now use equation (14) to rewrite equation (11):

$$i = G_1'(k_1) \cdot H(k_1,k_2). \tag{15}$$

In this equation, i and k_2 are both determined—i by assumption and k_2 by equation (10)—and we may solve for k_1 in terms of them. (The solution is unique, since $\frac{\partial i}{\partial k_1} < 0$ at all times.)

In this expanded model, as in the simpler one, if the interest rate is given, the capital-labor ratios in manufacturing are determined independently of the wage rate. To get this result we assumed only that wages were equal in the two industries. If this were not true, the result would not hold, but then also *only one* of the goods would be produced. The industry with the lower wage rate, say the capital goods industry, would not be able to attract labor, and all capital goods would have to be imported. The result just derived fails to hold *only* if there is no production either of consumption goods or of capital goods. (The latter is the hypothesis chosen by Habakkuk.)

We have shown that if the interest rate is fixed, the capital-labor ratio is too. What about the wage rate? Returning to the model with only one manufactured good, we find:

$$\frac{W}{P_M} = G(k) - k\,G'(k) \tag{16}$$

$$\frac{W}{P_A} = F(t) - t\,F'(t). \tag{17}$$

The ratio of wages to the price of manufactures is a function of k. If the interest rate is fixed, this ratio is too. This ratio is the "real wage" of the text for those parts of the discussion where agriculture was excluded from consideration. On the other hand, the ratio of wages to the price of agricultural goods is a function of t, which is not determined by the interest rate. As expected:

$$\frac{\partial\left(\frac{W}{P_A}\right)}{\partial t} = F'(t) - t\,F''(t) - F'(t) = -t\,F''(t) > 0. \tag{18}$$

Finally, from equation (7):

$$\frac{\partial k}{\partial i} = \frac{1}{\frac{\partial i}{\partial k}} = \frac{1}{G''(k)} < 0. \tag{19}$$