# FIXED CAPITAL IN AGRICULTURE: RICHARD JONES'S CRITIQUE OF RICARDO'S THEORY OF RENT

BY

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*Richard Jones's 1831 critique of David Ricardo's theory of rent is generally viewed as ill-founded. The present paper shows that Jones's* Essay on the Distribution of Wealth *contains an important analytical insight: Jones noticed that Ricardo's treatment of agricultural improvements was seriously incomplete, because it failed to accommodate the historically important case of agricultural improvements that involve the use of fixed capital. More generally, it is suggested that Jones was correct in pointing out that Ricardo had not properly taken into account fixed capital in his analysis of rent and of agricultural improvements.*

## I. INTRODUCTION

Few economic theorists, apart from Karl Marx, have found much merit in Richard Jones's 1831 critique of David Ricardo's theory of rent in his *Essay on the Distribution of Wealth* (1964). In Marx's judgment, "Jones marks a substantial advance on Ricardo, in his historical explanation as well as in the economic details" (1991,

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p. 323).[1] As regards the assessments of other major economic theorists, it suffices to quote John Stuart Mill's statement that Jones was "quite incapable of having a fundamentally new, and at the same time true, idea in Political Economy" (1972, pp. 698-699), Eugen von Böhm-Bawerk's verdict that Jones "adds nothing important to our knowledge" (1921, p. 90), and Alfred Marshall's perceptive remark that "Richard Jones had not fully grasped the modern distinction between generality of doctrines, or dogmas, and generality of analytical conceptions, or ideas" (1897, p. 117).[2] Joseph A. Schumpeter characterized Jones's objections to Ricardo's rent theory as "interesting examples of typical errors that are again and again committed by would-be theorists who have disdained to learn the art of theorizing" (1954, p. 676).[3]

While Jones is widely credited with having drawn attention to pre- and non-capitalistic forms of rent,[4] his critique of Ricardo's analysis of "farmers' rent" (which is Jones's term for rent that obtains with capitalistic production in competitive conditions) is generally viewed as ill-founded. The present paper intends to show that Jones's treatise contains an important *analytical* insight into competitive rent theory: Jones noticed that Ricardo's bipartite distinction of agricultural improvements into the two types of 'land saving' and 'capital (alias labor) saving' improvements is seriously incomplete, because it cannot properly accommodate the (historically) important case of agricultural improvements that involve the use of fixed capital. More generally, it is suggested that Jones was correct in pointing out that Ricardo had not properly taken into account fixed capital in his analysis of rent and of agricultural improvements, and had omitted to integrate the findings of the new chapter, "On Machinery," in the third edition of his *Principles* into his rent theory.

The structure of the paper is the following. In section II, the premises of Ricardo's theory of rent and of agricultural improvements are briefly recalled, in order to prepare the ground for a proper discussion of Jones's criticisms. Section III then provides a summary account of Jones's argument, according to which the increased application of fixed capital in agriculture can raise rents. This argument is sound and it can be formulated in a consistent way, as will be shown in section V below, but Jones's own presentation of it is marred with serious flaws. (William Whewell's alternative exposition of Jones's argument, which is also flawed, will be discussed in the Appendix.) In section IV, some textual evidence is provided for Ricardo's neglect of non-wage capital, and in particular fixed capital, in his analysis of rent and agricultural improvements. In section V, it is then shown by means of a simple numerical example

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[1]In his economic manuscript of 1861–63, Marx discussed Jones's contributions under the section heading "Jones's superiority over Ricardo in particular questions of the theory of rent and his mistakes in this field." For the reception of Marx's commentary on Jones's *Essay,* it is perhaps of some significance that the words "and his mistakes in this field" were omitted from the section heading in Kautsky's edition of Marx's economic manuscripts, later translated into English as *Theories of Surplus Value*. Kautsky's editorial intrusion may well have led later commentators to overrate Marx's esteem for Jones's contributions to rent theory. It should also be noted that the section on Jones was written in January 1863, *after* Marx had developed the essentials of his own rent theory "in the summer of 1862 through criticism first of Rodbertus and then of Ricardo, without any mention of Richard Jones" (Howard and King 1992, p. 79).

[2]Interestingly, Edgeworth's assessment (1894) of Jones's work, in both its historical and its analytical parts, is much more favorable.

[3]Biographical details and overall assessments of Jones's work are provided, for instance, in Whewell (1964) and Maas (2004).

[4]John Stuart Mill aptly described Jones's *Essay on the Distribution of Wealth* as a "copious repertory of valuable facts on the landed tenures of different countries" (1965, pp. 247–248).

that the introduction of agricultural improvements that involve the use of fixed capital can indeed raise rents on the basis of the set of assumptions underlying Ricardo's analysis. In addition, it is shown that this phenomenon can also arise in Ricardo's 'natural course' scenario, in which technical progress proper is set aside while known but hitherto unused methods of production may be introduced when it becomes profitable to do so. Section VI summarizes the main findings of the paper.

## II. THE PREMISES OF RICARDO'S ANALYSIS OF RENT AND OF AGRICULTURAL IMPROVEMENTS

For a proper assessment of Jones's criticism, it is necessary to recall briefly the premises of Ricardo's analysis of rent and of agricultural improvements. To simplify the exposition, suppose that only one agricultural commodity, corn, is produced by profit-seeking farmers under competitive conditions. In his analysis of rent, Ricardo generally takes as given: (i) the available amounts of the various types of land, which differ in terms of their fertility and/or their location; (ii) the set of available methods of cultivation from which cost-minimizing producers can choose; and (iii) the society's overall requirements for use; that is, the effective demand for corn. The latter is in turn taken to depend on the size of the capital stock. At an early stage of the accumulation process, the total demand for corn is relatively small, but with the increase of capital and population, the required amount of corn becomes ever larger. Accordingly, recourse must be had to less and less productive soils (extensive rent) or methods of land cultivation (intensive rent).

As regards the effects of agricultural improvements, Ricardo famously proclaimed in his *Essay on Profits* (the various volumes in *The Works and Correspondence of David Ricardo* are hereafter cited as *Works*):

> If the interests of the landlords be of sufficient consequence, to determine us not to avail ourselves of all the benefits which would follow from importing corn at a cheap price, they should also influence us in rejecting all improvements in agriculture, and in the implements of husbandry; for it is as certain that corn is rendered cheap, rents are lowered, and the ability of the landlord to pay taxes, is for a time, at least, as much impaired by such improvements, as by the importation of corn. To be consistent then, let us by the same act arrest improvement, and prohibit importation. (*Works* IV, p. 41)

In order to prove his proposition that the *immediate* effect of improvements is to raise the rate of profits and to lower rents, Ricardo provided a more detailed analysis of agricultural improvements in chapter 2 of his *Principles*. There he presented two numerical examples, because "improvements in agriculture are of two kinds: those which increase the productive powers of the land, and those which enable us, by improving our machinery, to obtain its produce with less labour" (*Works* I, p. 80).

He thus distinguished between what may be called 'land saving' and 'capital (alias labor) saving' improvements. Both kinds are invariably characterized by what Ricardo considered to be "the essential quality of an improvement"; that is, "to diminish the quantity of labour before required to produce a commodity" (*Works* I, p. 80). Ricardo mentioned as examples of the land-saving kind a more skillful rotation of crops and a better choice of manure, and concluded: "These improvements absolutely enable us to

obtain the same produce from a smaller quantity of land" (*Works* I, p. 80). On the contrary, agricultural improvements of the second kind

> do not increase the productive powers of the land; but they enable us to obtain its produce with less labour. They are rather directed to the formation of the capital applied to the land, than to the cultivation of the land itself. … *Less capital, which is the same thing as less labour, will be employed on the land*; but to obtain the same produce, less land cannot be cultivated. (*Works* I, p. 82; emphasis added)

In his analysis of the impact of improvements on income distribution, Ricardo generally assumed the total demand for corn to be given and unchanging. His principal proposition that agricultural improvements will generally raise profits and lower rents was explicitly premised on the assumption that the total demand for corn is the same in the *pre*-improvement situation and in the *post*-improvement situation. Ricardo was criticized for this, particularly by Thomas Robert Malthus, and he was ready to concede, both in his *Notes on Malthus* and in the third edition of the *Principles*,[5] that rents may ultimately rise due to agricultural improvements once time has passed and population growth has occurred. But the focus of his analysis in the chapter "On Rent" (and also in his earlier *Essay on Profits*) is on the more *immediate* impact on rent, holding population and the overall demand for agricultural output constant. A further characteristic feature of Ricardo's analysis of agricultural improvements is the assumption that improvements will raise outputs on the various types of land proportionately, so that the existing differentials remain the same. As Ricardo put it: "Improvements in agriculture, and in the division of labour, are common to all land; they increase the absolute quantity of raw produce obtained from each, but probably do not much disturb the relative proportions which before existed between them" (*Works* I, pp. 412–413).[6]

## III.  JONES'S ARGUMENT: INCREASED RENTS FROM THE APPLICATION OF FIXED CAPITAL IN AGRICULTURE

In his *Essay on the Distribution of Wealth,* Richard Jones provided a detailed historical account of different systems of land tenure, distinguishing between 'primary or peasants' rents' (which existed, and continue to exist, in pre- and non-capitalistic societies in the form of serf rents, metayer rents, ryot rents, or cottier rents) and 'farmers' rents,' which obtain in capitalistic societies in fully competitive conditions. The larger part of Jones's *Essay* was in fact concerned with the former types of rent, and he emphasized, quite rightly, that Ricardo's analysis of rent was strictly confined to the latter type—which, in Jones's view, meant that it was inapplicable to nine-tenths of the existing rents in the world. It needs to be stressed, therefore, that the following discussion will focus exclusively on a particular analytical point in Jones's critique of Ricardo's analysis of farmers' rents, and makes no attempt to provide an overall assessment of Jones's contributions to rent theory.[7]

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[5]See Ricardo (*Works* I, p. 412).
[6]For a discussion of some criticisms that have been raised against Ricardo's analysis of agricultural improvements, see Gehrke and Kurz (2003), and Gehrke, Kurz, and Salvadori (2003).
[7]For such an attempt, see Miller (1977).

### *'Capital Applied in the Support of Labor' versus 'Auxiliary Capital'*

In Jones's view, an indispensable prerequisite for a proper analysis of capital accumulation in the presence of land scarcity is to distinguish clearly between *wage capital* and *non-wage capital*. Referring specifically to Ricardo's theory of extensive differential rent, Jones observed: "We must carefully distinguish between the effects of increasing capital when it is applied to the support of *additional labor*, and when it is applied as *auxiliary* to the industry of the laborers already employed, without any increase in their number" (1964, p. 218).

He suggested that the importance of this distinction had escaped Ricardo's attention, because he had been in the habit of taking all capital to be fully resolvable into 'immediate' and 'past' labor, and had tended to use the terms "capital" and "labor" as interchangeable. Characteristically, Ricardo had defined agricultural improvements of the capital-saving type as those that employ "less capital, *which is the same thing as less labour*" (*Works* I, p. 82; emphasis added). According to Jones, this habit of reducing auxiliary capital to previously expended labor had prevented Ricardo from noticing an important difference that exists between the two forms of capital accumulation:

> When a given quantity of additional capital is applied in the shape of the results of past labor, to assist the laborers actually employed, *a less annual return will suffice to make the employment of such capital profitable*, and, therefore, permanently practicable, than if the same quantity of fresh capital were expended in support of additional laborers. (1964, p. 224; emphasis added)

As Jones emphasized, this statement refers specifically to auxiliary capital in the shape of "implements, drains, walls, fences, etc."; that is, to *fixed capital*. Whereas advanced wages (and, of course, circulating capital advances generally) must be fully recovered from the annual returns, together with normal profits, at the end of the production period, with fixed capital the annual returns need only cover the charge for the annual wear and tear plus the interest on the capital advanced. For this reason the application of fixed capital can be profitable even if its use is associated with a much smaller *annual* return than that which would have been necessary if the same amount of capital had been expended in support of additional agricultural workers. Jones illustrated his argument with the following numerical example:

> Let us suppose £100. employed upon the soil in the maintenance of three men, producing their own wages, and 10 per cent. profit on them, or £110. Let the capital employed … be doubled. And first let the fresh capital support three additional laborers. In that case, the increased produce must consist of the full amount of their wages, and the ordinary rate of profit on them. It must consist, therefore, of the whole £100., and the profit on it; or of £110. Next let the same additional capital of £100. be applied in the shape of implements, manures, or any results of past labor, while the number of actual laborers remains the same. And let this auxiliary capital last on the average five years: the annual return to repay the capitalist must now consist of £10. his profit, and of £20. the annual wear and tear of his capital: or, £ 30. will be the annual return, necessary to make the continuous employment of the second £100. profitable, instead of £110., the amount necessary when direct labor was employed by it. (1964, pp. 224–225)

The point made by Jones in this passage is rather simple. If the additional £100 are applied in employing three additional workers on the land (in addition to the three workers who were already employed before), then the value of the additional *annual* produce must be £110. But if the additional £100 were instead used to supply the three workers with some long-lived fixed capital items ('implements'), the value of the additional *annual* produce can be much smaller. Up to this point, the reader will probably find Jones's argument both unoriginal and uncontroversial. (It should be noted, though, that Jones's calculation of the annual charge for the wear and tear of the fixed capital is rather crude.) However, Jones then put forward a proposition that squarely contradicts Ricardo's theory of rent. He contended that the application of auxiliary capital in the shape of fixed capital must be considered as a separate, independent cause of a rise of rents, besides the deteriorating agricultural productivity emphasized by Ricardo, which results from the need to have recourse to inferior soils ('extensification') or methods of land cultivation ('intensification'). Moreover, he claimed that by the introduction of fixed-capital-using methods in agriculture rents are raised in absolute terms, but are simultaneously diminished as a share in total output or gross revenue. Unfortunately, however, Jones presented his essentially correct argument in a form that is fallacious.

## *Jones's Fallacious Presentation of the Argument*

Jones claimed that capital accumulation as such, independent of any necessity to have recourse to inferior soils, will cause rising rents in absolute terms, because the outputs obtained on the soils already under cultivation are increased proportionately by the application of additional capital on each and every type of land, so that the absolute amounts of the output differentials, and thus rents, are raised: "The general accumulation of the capital employed in cultivation, while it augments the produce of all gradations of soil, somewhat in proportion to their original goodness, must of itself raise rents; without reference to any progressive diminution in the return to the labor and capital employed" (1964, p. 195).

Jones further claimed that rents are invariably raised in absolute terms by the application of additional capital, no matter whether this consists of additional wage capital or of additional auxiliary capital, but that the effects on the rent share will differ significantly in the two cases. Whereas the application of additional wage capital will increase the rent share, the application of additional capital in the form of fixed capital will generally reduce it. In order to demonstrate this, Jones produced a simple numerical example, which was meant to show, first, that the application of additional capital always increases the total amount of rent, and, second, that the accumulation of auxiliary capital *in the shape of fixed capital* must necessarily be associated with a decline of the share of rent in total output:

For instance, let [land of type] *A*, *B*, *C*, and *D* produce as follows:

| *A* | *B* | *C* | *D* |
|------|------|------|------|
| £110. | £115. | £120. | £130. |

The differences, surplus profits, or rents on *B*, *C*, and *D*, will be 5 + 10 + 20, or together £35. Let an additional £100., employed in the maintenance of additional labor, raise their produce to

| *A* | *B* | *C* | *D* |
|------|------|------|------|
| £220. | £230. | £240. | £260. |

Rents will be doubled. The addition to them will amount to another £35. But let the additional capital of £100. be applied in the results of past labor, auxiliary to the labor already employed; and let £30. be sufficient to pay the profits of that capital, and replace its annual wear and tear on $A$. If $B$, $C$, and $D$ yield a produce to the new capital fully proportioned to their original superiority over $A$, still their produce will not exceed (suppose,)

$$A\,140, B\,(115+32)=147, C\,(120+34)=154, D\,(130+36)=166.^{[8]}$$

The joint rents of the three will now be £47. instead of £35.: but instead of rents being doubled, and, as in the last instance, the addition amounting to £35., it will amount only to £12.; although, in the mean time, the amount of profits realized by the farmers will have doubled, as in the former case. (1964, pp. 226–227)

Jones concluded:

With the increase of the mass of auxiliary capital employed in agriculture rents will rise, *from the unequal effects of that capital on soils of unequal goodness*. But the rise of rents from the employment of any given quantity of auxiliary capital, will be less than that which would take place from the employment of an equal amount of capital in the employment of additional labor. (1964, p. 225; emphasis added)

There are several problems with Jones's numerical example. To begin with, his argument *must* refer to the case of agricultural improvements, rather than to the case of capital accumulation in a given state of technical knowledge. For, without improved methods of cultivation, which had not been available before, it cannot be supposed that an additional amount of wage capital can be employed on each of the four types of land that yields the same returns as the previous amount (that is, additional returns of £110, 115, 120, 130). If this were possible without any newly available methods of land cultivation, the initial four portions of capital (£400) would of course have been expended on lands of type $D$ and $C$ alone (while lands of type $B$ and $A$ would not have been cultivated at all): the same capital then yields £500 (= 260 + 240) instead of £475 (110 + 115 + 120 + 130). Accordingly, the possibility of applying additional capital of £100 on each type of land in this way *must* be supposed to emerge only at some later stage of the accumulation process, when all four types of land have already been cultivated (by expending £100 on each), from agricultural improvements that have become newly available.[9] However, if we take Jones's argument—unlike he himself presented it—as referring to the case of agricultural improvements, then we must also, in order to be consistent with the premises of Ricardo's analysis of agricultural improvements, take as given the society's 'requirements for use'; that is, the total demand for agricultural produce—in which case rents will clearly fall rather than rise. (This is because in the post-improvement situation, with a given and unchanged demand for agricultural produce, lands of type $B$ and $A$ need not be cultivated any more.) The same reasoning applies also to the second part of Jones's numerical

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[8]Jones apparently assumes that supplying the workers employed on the different types of land with the same fixed capital items will increase their annual output differently. The resulting increases on lands of type $B$, $C$, and $D$ are taken to be "fully proportioned to their original superiority over $A$"; that is, the proportions 30 : 32 : 34 : 36 are supposed to be (very roughly) equivalent to the proportions 110 : 115 : 120 : 130.

[9]See, on this point, also Cannan (1967, p. 264).

example concerning the introduction of fixed capital (where the application of additional auxiliary capital is supposed to yield additional returns of £30, 32, 34, 36). This also cannot possibly refer to capital accumulation in a given state of technical knowledge, because then the auxiliary capital would already have been introduced on land of type *D*, because it is profitable to do so, before all the other types of land were taken into cultivation. To conclude: if it is interpreted as referring to the case of capital accumulation in a given state of technical knowledge, Jones's reasoning is seriously flawed. If, on the other hand, his argument is taken to refer to the case of agricultural improvements, it does not contradict the results of Ricardo's analysis of agricultural improvements, if the latter's premise of given requirements for use—that is, a given and unchanging demand for agricultural output—is adhered to. Moreover, Ricardo had fully acknowledged that improvements that alter the relative productivity of the lands already under cultivation may raise rents, and therefore Jones's criticism is also invalidated by his reference to "unequal effects from the application of capital on soils of unequal goodness." However, this is a red herring, because the principal flaw in Jones's exposition of his argument, if it is interpreted as referring to agricultural improvements, consists in the fact that he did not take into account Ricardo's assumption of an unchanged demand for agricultural produce. Jones's presentation of his argument was thus clearly defective—and this on several counts.[10] But Jones's proposition, according to which the application of agricultural methods that involve the use of fixed capital can be a cause of a rise in rents, is indeed a sound one, as will be shown in section V below.

Before we proceed, it should be noted that Jones presented his argument not only as a theoretical proposition deduced from abstract premises and hypothetical numerical examples, but also as an *empirical* or *inductive* critique of Ricardo's theory. He claimed that Ricardo's rent theory was squarely contradicted by the empirical facts, which rather supported his own explanation of the rise of rents in England. According to Jones, Ricardo's theory of rent had two, broad, empirical implications:

> If rents … should ever rise from that cause alone, which has been so confidently stated by Mr. Ricardo, to be the *sole* possible cause of a rise of rents, namely 'the employment of an additional quantity of labor with a proportionally less return,' and a consequent transfer to the landlords of a part of the produce before obtained on the better soils; then the average *proportion* of the gross produce taken by the landlords as rent, will necessarily increase. [Second,] the industry of a larger proportion of the population must be devoted to agriculture. (1964, pp. 280 and 281)

The two alleged implications of Ricardo's theory—that is, a rising rent share in total aggregate income and an increasing employment share of the agricultural sector—were then confronted with the available empirical data, which Jones suggested could be summarized in the following terms:

> The statistical history of England presents to us, prominently, three facts: First, there has been a spread of tillage accompanied by a rise in the general rental of the country; Secondly, there has been a *diminution of the proportion* of the people employed in agriculture; Thirdly, there has been a decrease in the landlord's *proportion* of the produce. (1964, p. 282)

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[10]Whewell's alternative presentation of Jones's argument, which is explicitly in terms of agricultural improvements, is discussed in the Appendix.

These empirical 'facts' are then said to be fully in line with Jones's principal proposition: that the rise of rents in England had been caused first and foremost by the increased application of fixed capital in agriculture, and not by the extension of cultivation to inferior soils.

## IV. RICARDO'S CHAPTER "ON MACHINERY" AND HIS NEGLECT OF FIXED CAPITAL IN HIS THEORY OF RENT AND AGRICULTURAL IMPROVEMENTS

In the following, some textual evidence is provided to show that Jones was justified in criticizing Ricardo for his neglect of fixed capital in his analysis of rent and agricultural improvements. We then move on to show that Ricardo had been aware of the point stressed by Jones in relation to fixed capital; namely, that fixed capital can be profitably introduced even though the annual gross output is smaller than if the same amount of capital is applied as circulating capital. This point was indeed stressed by Ricardo himself with respect to the substitution of machinery for labor in chapter 31 of his *Principles*.

### Wage Capital, Non-wage Capital, and Fixed Capital in Ricardo's Theory of Rent

In chapter 2 of the *Principles,* Ricardo expounded his theory of rent and of agricultural improvements *as if* the capital applied to the land consisted only of wage capital. He was, of course, aware of the existence of agricultural methods that involve the use of fixed capital—and indeed referred to fixed capital explicitly in the chapter "On Rent," first, in connection with his definition of rent,[11] and then also in his discussion of different types of agricultural improvements.[12] But these purely verbal allusions to fixed capital cannot alter the fact that Ricardo's exposition of the analytical argument concerning differential rent, of both the extensive and the intensive type, was based on the simplifying assumption that the farmers' advances consist only of 'immediate' and 'past' wages, and that these capital advances must be fully recovered at the end of the annual production cycle, together with normal profits.

The only instance where Ricardo showed some awareness of the need to distinguish clearly between fixed and circulating agricultural capital is in a short passage in the *Essay on Profits* of 1815, from which the analytical core of the theory of growth and distribution that he later expounded in the *Principles* has emanated. This pamphlet, which had a clear propagandistic purpose, contains a striking remark on the different distributional effects of capital accumulation when fixed capital—as opposed to circulating capital—is involved. In an explanatory note, which he appended to the well-known table of the *Essay*, Ricardo stated:

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[11]See Ricardo's definition of rent "in the strict sense"; that is, rent *net* of any charges for depreciation and interest on "farming buildings" or on "hedges, fences, and walls" (*Works* I, p. 67).

[12]In his discussion of agricultural improvements Ricardo referred, inter alia, to "improvements in agricultural implements, such as the plough and the thrashing machine" (*Works* I, p. 82).

> It is scarcely necessary to observe, that the data on which this table is constructed are assumed, and are probably very far from the truth. They were fixed on as tending to illustrate the principle … *In proportion as the capital employed on the land, consisted more of fixed capital, and less of circulating capital, would rent advance, and profits fall, less rapidly.* (*Works* IV, pp. 15–16; emphasis added)

No explanation is provided for the final statement italicized above, and it does not recur in the *Principles*. A possible explanation is that the society's overall demand for corn can be supposed to be proportional to the number of workers employed in agriculture, which in turn can be supposed to be diminished by the application of fixed-capital-using agricultural methods. The chapter "On Rent" in the *Principles* contains a passage that clearly points in this direction—although, curiously enough, this very same passage also shows Ricardo's failure to distinguish properly between wage capital and non-wage capital:

> Population regulates itself by the funds which are to employ it, and therefore always increases or diminishes with the increase or diminution of capital. Every reduction of capital is therefore necessarily followed by a less effective demand for corn, by a fall of price, and by diminished cultivation. (*Works* I, p. 78)

Ricardo here supposes the effective demand for corn to be regulated by the size of the population, the size of the population in turn to be regulated by the demand for labor, and the demand for labor to be regulated by the total amount of capital advanced—as if all capital consisted only of wage capital (or of wage and non-wage capital in a fixed proportion).

## A Gross Produce-Reducing Form of Technical Change

In the opening paragraph of the newly introduced chapter "On Machinery" in the third edition of the *Principles,* Ricardo explained his reasons for recanting his former views on machinery in the following terms: "My mistake arose from the supposition, that whenever the net income of a society increased, its gross income would also increase; I now, however, see reason to be satisfied that the one fund … may increase, while the other … may diminish" (*Works* I, p. 388).

Ricardo then expounded his new insight by means of a simple numerical example, in which the introduction of machinery by a representative capitalist, who "carries on the joint business of a farmer, and a manufacturer of necessaries" (ibid.), results in a diminution of the annual gross produce.[13] He then demonstrated that the same phenomenon can also arise from the introduction of machinery in some branch of the manufacturing sector, and concluded: "If these views be correct, it follows … that the motives for employing machinery are always sufficient to insure its employment, if it will increase the net produce, *although it may, and frequently must, diminish both the quantity of the gross produce, and its value*" (*Works* I, pp. 391–392; emphasis added).

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[13]In this example, the gross income is taken to consist only of profits and wages; and the net income, of profits alone. That is, Ricardo deliberately set aside rent (presumably in order to focus attention on the main analytical issue), so that the impact of the introduction of machinery on rent could not be considered.

This important new finding was not integrated into the theory of rent and agricultural improvements, the exposition of which remained unaltered in the third edition of the *Principles*. Ricardo in fact retained several passages that are incompatible with this new finding. The following passage in chapter 32, for instance, was left untouched in the third edition of the *Principles*:

> Nothing can raise rent, but a demand for new land of an inferior quality, or some cause which shall occasion an alteration in the relative fertility of the land already under cultivation. Improvements in agriculture, and in the division of labour, are common to all land; *they increase the absolute quantity of raw produce obtained from each,* but probably do not much disturb the relative proportions which before existed between them. (*Works* I, pp. 412–413; emphasis added)

The assertion that agricultural improvements must invariably increase the quantity of raw produce that is obtained on each type of land is clearly in contradiction with the new finding of chapter 31. Ricardo thus omitted to integrate into his theory of rent and agricultural improvements the very point he himself had made so forcefully in the newly inserted chapter "On Machinery": that fixed capital can be profitably introduced even if its use is associated with a reduction in the annual amount of produce.

## V. INCREASED RENTS FROM AGRICULTURAL METHODS THAT INVOLVE THE USE OF FIXED CAPITAL: A SIMPLE EXAMPLE

This section investigates whether the application of fixed capital in agriculture can cause rents to rise, as suggested by Jones. A simple numerical example will show that this is indeed possible, because it can be profitable to introduce fixed-capital-using methods even if the annual output per unit of land (as compared with the previously used methods) is thereby reduced. If the demand for agricultural produce is supposed to be unchanged, as was generally assumed by Ricardo, the application of such methods can shift the extensive margin to inferior soils, and thus lead to increased rents. It needs to be stressed that this result, while it clearly shows that Jones was correct in criticizing Ricardo for his neglect of fixed capital in his analysis of rent and agricultural improvements, is not derivable from a "one-to-one mapping" of Jones's assumptions. In particular, the following example has been constructed in such a way that the existing output differentials between the various types of land are preserved. Unlike in Jones's numerical example, which in section III has been shown to be flawed, in the following example the increase in rent arises from the need to extend the cultivation to inferior types of land, because the output produced on the intra-marginal lands with the fixed-capital-using methods is smaller than the one that was produced on the same types of land with the labor-using methods.

*A Simple Example*

Consider the case of pure extensive rent, with a single agricultural commodity (corn), and four qualities of land (*A*, *B*, *C*, *D*). Suppose that in the pre-improvement situation there is only one method for cultivating each type of land, methods (1)–(4), while in the post-improvement situation there are three methods for cultivating each

type of land: (*i*) methods (1)–(4), which use (homogeneous) labor and a single type of land; (*ii*) methods (6)–(9), which use labor and a single type of land, together with a new machine; and (*iii*) methods (10)–(13), which use labor and a single type of land in combination with a one-year-old machine. For simplicity, assume that there is only one method for producing new machines, method (5), and that machines are produced by "unassisted" labor in a single construction period and exhibit constant physical efficiency during their lifetime, which, for simplicity, is assumed to be only two years.

Table 1 shows the set of available production methods at the unit output level. The coefficients give the input requirements of land ($b_{j,i}$), labor ($l_i$), and machines ($m_{k,i}$) per unit of output, with $j = A, B, …, D$, $i = 1, 2, …, 13$, and $k = 0, 1$. With regard to method (8), for instance, the corresponding row should be read as follows: by combining 1.5 units of land of type $C$ with 0.75 units of labor and one new machine, one unit of corn plus a one-year-old machine is produced.[14] Suppose that the available amount of each quality of land is 30 acres, and that the (subsistence) wage rate is given at 0.2 tons of corn per unit of labor. Wages must be advanced at the beginning of the production period (*ante factum* payment of wages), while rents and profits accrue at the end of the annual production cycle (*post factum* payment of rents and profits). Suppose further that at first, only methods (1)–(4) are available and that the given "requirements for use"—that is, the needs and wants of the population—amount to 70 tons of corn. Then, methods (1), (2), and (3) are operated by cost-minimizing producers; land of type $D$ is not cultivated at all and land of type $C$ is the marginal land. When corn is used as the numéraire, $\overline{w}$ designates the given wage rate (in corn), $r$ is the rate of profits, and $q_i$ is the rent rate (per unit of land) on land of type $j$, then the following equations must be satisfied in the pre-improvement situation:

$$\overline{w}l_1(1+r) + q_1 b_{A1} = 1$$
$$\overline{w}l_2(1+r) + q_2 b_{B2} = 1 \qquad (1)$$
$$\overline{w}l_3(1+r) = 1$$

The rate of profits is 48%, and the corn rent per acre is 0.15 tons of corn on land of type $A$ and 0.1 tons of corn on land of type $B$. Accordingly, the total rent amounts to 7.5 tons of corn.

Suppose now that a new set of methods becomes available for cultivating the various types of land—methods (6)–(13)—which use (a particular type of) land, labor, *and machines* as inputs. In addition, there is also a newly available method for producing new machines: method (5). Cost-minimizing corn producers would adopt these methods, because it is profitable to do so. However, in order to meet the given demand of 70 tons of corn, it is no longer sufficient to cultivate only lands of type $A$, $B$, and $C$: land of type $D$ must now also be cultivated. In the post-improvement situation, the following equations must be satisfied:

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[14]Note that the alphabetical ordering of the different types of land is ascending from the lowest ($A$) to the highest ($D$) labor input requirement per unit of output. Accordingly, land of type $A$ is the 'most fertile' one and land of type $D$ is the 'least fertile' one. There is thus no correspondence with Jones's numerical example, where land of type $D$ is supposed to be the 'most fertile' one.

**Table 1.** Set of available production methods

| Inputs | | | | | | | | Outputs | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Land of type ($b_{ji}$) | | | | Labor ($l_i$) | New machines ($m_{0i}$) | Used machines ($m_{1i}$) | | Corn | New machines | Used machines |
| A | B | C | D | | | | | | | |
| (1) 1 | | | | 2.87 | | | $\rightarrow$ | 1 | | |
| (2) | 1 | | | 3.04 | | | $\rightarrow$ | 1 | | |
| (3) | | 1 | | 3.38 | | | $\rightarrow$ | 1 | | |
| (4) | | | 1 | 4 | | | $\rightarrow$ | 1 | | |
| (5) | | | | 2.59 | | | $\rightarrow$ | | 1 | |
| (6) 1.5 | | | | 0.25 | 1 | | $\rightarrow$ | 1 | | 1 |
| (7) | 1.5 | | | 0.50 | 1 | | $\rightarrow$ | 1 | | 1 |
| (8) | | 1.5 | | 0.75 | 1 | | $\rightarrow$ | 1 | | 1 |
| (9) | | | 1.5 | 1 | 1 | | $\rightarrow$ | 1 | | 1 |
| (10) 1.5 | | | | 0.25 | | 1 | $\rightarrow$ | 1 | | |
| (11) | 1.5 | | | 0.50 | | 1 | $\rightarrow$ | 1 | | |
| (12) | | 1.5 | | 0.75 | | 1 | $\rightarrow$ | 1 | | |
| (13) | | | 1.5 | 1 | | 1 | $\rightarrow$ | 1 | | |

$$\overline{w}l_m(1+r) = p_{m0}$$
$$\overline{w}l_6(1+r) + p_{m0}(1+r) + q_1 b_{A,6} = 1 + p_{m1}$$
$$\overline{w}l_7(1+r) + p_{m0}(1+r) + q_2 b_{B,7} = 1 + p_{m1}$$
$$\overline{w}l_8(1+r) + p_{m0}(1+r) + q_3 b_{C,8} = 1 + p_{m1}$$
$$\overline{w}l_9(1+r) + p_{m0}(1+r) = 1 + p_{m1} \tag{2}$$
$$\overline{w}l_{10}(1+r) + p_{m1}(1+r) + q_1 b_{A,10} = 1$$
$$\overline{w}l_{11}(1+r) + p_{m1}(1+r) + q_2 b_{B,11} = 1$$
$$\overline{w}l_{12}(1+r) + p_{m1}(1+r) + q_3 b_{C,12} = 1$$
$$\overline{w}l_{13}(1+r) + p_{m1}(1+r) = 1$$

In the post-improvement situation, the rate of profits is 50%, and the rents per acre on lands of type $A$, $B$, and $C$ amount to, respectively, 0.15, 0.1, and 0.05 tons of corn. Accordingly, the total rent amounts to 9 tons of corn. (The price of a new machine, $p_{m0}$, is 0.78 tons of corn, and the price of a one-year-old machine, $p_{m1}$, is 0.47 tons of corn.) Note that the numerical values of the production coefficients have deliberately been chosen so as to leave the rents per acre on lands of types $A$, $B$, and $C$ the same as before. Accordingly, the increase in total rent from 7.5 to 9 tons of corn is *not* caused by an alteration in the existing cost differentials between the various types of lands.

The example shows that the introduction of agricultural improvements that involve the use of fixed capital can shift the agricultural margin to inferior soils. It is a specific characteristic of such improvements that their introduction can be profitable even if

they decrease, rather than increase, the annual output per unit of land (as compared with the previously used methods). However, it could be objected that precisely the same phenomenon—a shift of the extensive margin to inferior soils in the post-improvement situation—can also occur with agricultural improvements that do *not* involve fixed capital. This is indeed true, as the following example shows. If, instead of methods (5)–(13), methods (14)–(17) were available in the post-improvement situation, the cultivation of land would also be extended to land of type *D* (in the new long-period position, the rate of profits is 400% and the rents on lands of types *A*, *B*, and *C* are, respectively, 1/2, 1/3, and 1/6).

One might be inclined to suppose, therefore, that the phenomenon under consideration is independent of the use of fixed capital, and results merely from the fact that we have considered agricultural improvements that are characterized by falling labor coefficients and rising land coefficients.

In order to show that the introduction of fixed-capital-using methods in agriculture may indeed give rise to specific effects that are peculiar to them, and that cannot possibly arise without fixed capital, we must abandon the assumption that these methods are improvements that become newly available only at some later stage of economic development. Let us assume, then, that *all* methods in Table 1 (but not those in Table 2) are available from the beginning. Let us further suppose that the society's requirements for use gradually increase from 0 to 70 tons of corn. Table 3 shows the methods that are adopted by cost-minimizing corn producers at each level of output.

The fixed-capital-using methods, although they have been available all along, are introduced only when the total demand for corn exceeds 60 tons. At earlier stages of the accumulation process with a lower demand for corn, the labor-using methods are cost-minimizing. It needs to be emphasized that the rent that emerges on lands of type *B* and *C* when the "requirements for use" exceed 60 tons of corn is not some new type of rent but standard extensive differential rent. However, if methods (5)–(13) did not exist, the farmers would have adopted methods (1)–(3), land of type *C* would have yielded no rent, and the total rent would have been smaller. What gives rise to the emergence of rent on land of type *C*, and of higher rent rates on lands of type *A* and *B*, is the gross produce-reducing form of the fixed-capital-using methods of land cultivation. This phenomenon cannot possibly occur with circulating-capital-using methods, because a method that was not adopted previously, from the available set of known methods, could be introduced on lands of type *A* and *B* at some later stage of the accumulation process *only if* it is land-saving; that is, if it is characterized by less land input per unit of output.[15] On the contrary, the introduction of fixed-capital-using methods at some later stage of economic development need not necessarily be associated with a more intensive use of land. This is so because with the gradual extension of cultivation to inferior soils, and the associated fall in the general rate of profits*,* it can become profitable to introduce such methods also on

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[15]If we had supposed methods (14)–(17), instead of methods (5)–(13), to have been available from the beginning, then these methods would have been adopted by cost-minimizing producers from the start, when the requirements for use were gradually increased from 0 to 70 tons of corn. Method (1) would then have been introduced, and used side by side with method (14) on land of type *A*, only when the society's requirements for corn exceed 80 tons of corn.

**Table 2.** Newly available methods in the post-improvement situation (no fixed capital)

| | Inputs | | | | | | | | Outputs | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Land of type | | | | | | | | | | |
| | $A$ | $B$ | $C$ | $D$ | Labor | New machines | Used machines | | Corn | New machines | Used machines |
| (14) | 1.5 | | | | 0.25 | | | $\rightarrow$ | 1 | | |
| (15) | | 1.5 | | | 0.50 | | | $\rightarrow$ | 1 | | |
| (16) | | | 1.5 | | 0.75 | | | $\rightarrow$ | 1 | | |
| (17) | | | | 1.5 | 1 | | | $\rightarrow$ | 1 | | |

lands of a better quality. This phenomenon is peculiar to the substitution of fixed-capital-using methods for labor-using methods—a substitution that was explained at some length in section 5 of chapter 1 and in chapter 31 of the *Principles*, and is now known as the so-called Ricardo effect.[16]

In the example considered above, the Ricardo effect can be illustrated by studying the development of the unit costs in corn production, *exclusive of rent*, when fixed-capital-using methods are employed, relative to the development of the unit costs (also exclusive of rent) of the labor-using methods. The former are given by

$$\bar{w}(1+r)\left(l_i + l_m \frac{r(1+r)^n}{(1+r)^n - 1}\right),[17] \text{ for } i = 6, 7, \ldots, 13, \text{ and the latter are given by } \bar{w}(1+r)l_i^*,$$

for $i = 1, 2, \ldots, 4$. The fixed-capital-using methods (non-starred variables) will be introduced on land of type $j$ ($j = A, B, C, D$), if their unit costs (excluding rent) on land of type $j$ are smaller than those of the corresponding labor-using methods (starred variables); that is, they will be introduced, if

$$\bar{w}(1+r)\left(l_i + l_m \frac{r(1+r)^n}{(1+r)^n - 1}\right) < \bar{w}(1+r)l_i^*, \tag{3a}$$

$$\text{or} \qquad \left(l_i + l_m \frac{r(1+r)^n}{(1+r)^n - 1}\right) < l_i^*. \tag{3b}$$

Inequality (3b) shows why it can become profitable to introduce fixed-capital-using methods at some later stage of the accumulation process, while it was not profitable to do so at an earlier stage. At high rates of profit, corresponding to an early stage of the accumulation process and little demand for corn, the fixed-capital-using methods exhibit higher unit costs (exclusive of rent) than the labor-using methods. But when capital is

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[16]See Ricardo (*Works* I, pp. 40–41). For a critical discussion of the meaning and validity of the Ricardo effect, see Gehrke (2003).

[17]Because of our simplifying assumption that the machine exhibits constant efficiency during its lifetime, we can calculate the annual charge for depreciation and interest by applying the annuity formula $p_{m0} \frac{r(1+r)^n}{(1+r)^n - 1} = \bar{w}(1+r)l_m \frac{r(1+r)^n}{(1+r)^n - 1}$. In the example the lifetime of the machine is $n = 2$.

**Table 3.** Methods used at each level of output

| Amount of corn | Methods used | Rate of profits | Rent rate on land of type $A$, $B$, $C$ | | |
|---|---|---|---|---|---|
| $0 < x \leq 30$ | (1) | 74 % | 0 | 0 | 0 |
| $30 < x \leq 60$ | (1), (2) | 65 % | 0.05 | 0 | 0 |
| $60 < x \leq 80$ | (5)-(13) | 50 % | 0.15 | 0.1 | 0.05 |

accumulated and the population increases, the demand for corn rises and the rate of profit falls. At low rates of profit, corresponding to a later stage of the accumulation process with a higher demand for corn, the unit costs of the fixed-capital-using methods become lower than those of the labor-using methods.[18] Accordingly, the fixed-capital-using method is introduced on the marginal land as soon as its unit costs (exclusive of rent) are not larger than those of the labor-using method.

In the simple case under consideration—that is, without any non-wage capital other than machines—it is always true that when the fixed-capital-using methods exhibit lower unit costs than the labor-using methods on the marginal land, then they also exhibit lower unit costs on all the intra-marginal lands. Accordingly, they will always be introduced on all cultivated types of land simultaneously.

## VI. CONCLUSION

In this paper it was first shown that Richard Jones failed to provide a valid criticism of Ricardo's analysis of rent and agricultural improvements, because his own exposition of his (essentially correct) argument concerning the possibility of rising rents from the increased use of fixed capital is seriously flawed. It was then suggested that Jones was correct in pointing out that Ricardo had not properly taken into account non-wage capital, and in particular fixed capital, in his analysis of rent and of agricultural improvements, and had omitted to integrate the findings of the chapter "On Machinery" into his rent theory. By means of a simple numerical example, it was then shown that the introduction of fixed-capital-using methods in agriculture can indeed cause rents to rise, and that this phenomenon can arise both in the case of newly invented agricultural improvements that involve fixed capital and in the case of Ricardo's 'natural course' scenario, in which known but hitherto unused methods of production may be introduced when it becomes profitable to do so.

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[18]As Ricardo put it in the chapter "On Machinery": "With every increase of capital and population, food will generally rise, on account of its being more difficult to produce. The consequence of a rise of food will be a rise of wages, and every rise of wages will have a tendency to determine the saved capital in a greater proportion than before to the employment of machinery. Machinery and labour are in constant competition, and the former can frequently not be employed until labour rises" (*Works* I, p. 395).

# REFERENCES

Böhm-Bawerk, Eugen von. [1884] 1921. *Kapital und Kapitalzins. Erste Abteilung. Geschichte und Kritik der Kapitalzins-Theorien*. Innsbruck. Fourth edition. Jena: Gustav Fischer.

Brems, Hans. 1970. "Ricardo's Long-run Equilibrium." *History of Political Economy* 2 (2): 419–431.

Campanelli, Guiliana. 1982. "W. Whewell's Contribution to Economic Analysis: The First Mathematical Formulation of Fixed Capital in Ricardo's System." *The Manchester School* 50: 248–265.

Campanelli, Guiliana. 1998. "Early Mathematical Formulations in English-speaking Countries." In Heinz D. Kurz and Neri Salvadori, eds., *The Elgar Companion to Classical Economics*. Volume I. Cheltenham: Edward Elgar, pp. 235–240.

Cannan, Edwin. [1893] 1967. *A History of the Theories of Production and Distribution in English Political Economy from 1776 to 1848*. New York: A. M. Kelley.

Cochrane, James L. 1970. "The First Mathematical Ricardian Model." *History of Political Economy* 2 (2): 419–431.

Cochrane, James L. 1975. "William Whewell's Mathematical Statements." *The Manchester School* 43: 396–400.

Creedy, John. 1989. "Whewell's 'Translation' of J. S. Mill." *Scottish Journal of Political Economy* 36: 266–281.

Edgeworth, Francis Ysidro. 1894. "Entry 'Richard Jones'." In Robert Harry Inglis Palgrave, ed., *Palgrave's Dictionary of Political Economy*. Volume II. London: Macmillan.

Gehrke, Christian. 2003. "The Ricardo Effect: Its Meaning and Validity." *Economica* 70: 143–158.

Gehrke, Christian, and Heinz D. Kurz. 2003. "On Some Criticisms of Ricardo's Discussion of Agricultural Improvements." In George Argyrous, Mathew Forstater, and Gary Mongiovi, eds., *Growth, Distribution and Effective Demand: Essays in Honor of Edward J. Nell*. New York: M. E. Sharpe, pp. 327–345.

Gehrke, Christian, Heinz D. Kurz, and Neri Salvadori. 2003. "Ricardo on Agricultural Improvements: A Note." *Scottish Journal of Political Economy* 50: 291–296.

Henderson, James P. 1985. "The Whewell Group of Mathematical Economists." *The Manchester School* 53: 404–431.

Henderson, James P. 1996. *Early Mathematical Economics. William Whewell and the British Case*. Lanham, Boulder, New York, London: Rowman & Littlefield.

Jones, Richard. [1831] 1964. *An Essay on the Distribution of Wealth, and on the Sources of Taxation. Part I. Rent*. New York: A. M. Kelley.

Maas, Harro. 2004. "Entry 'Richard Jones'." In Donald Rutherford, ed., *Biographical Dictionary of British Economists*. Volume 1. Bristol: Thoemmes Press, pp. 613–617.

Marshall, Alfred. 1897. "The Old Economists and the New." *Quarterly Journal of Economics* 11: 115–135.

Marx, Karl. [1861–63] 1991. *Economic Manuscript of 1861–63. A Contribution to the Critique of Political Economy ["Theories of Surplus Value"]*. In *Karl Marx, Frederick Engels: Collected Works*. Volume 33. New York: International Publishers.

Mill, John Stuart. [1848] 1965. *Principles of Political Economy with Some of their Applications to Social Philosophy*. In *Collected Works of John Stuart Mill*. Volume 2. Toronto: University of Toronto Press.

Mill, John Stuart. 1972. *The Later Letters*. In *Collected Works of John Stuart Mill*. Volume 15. Toronto: University of Toronto Press.

Miller, William L. 1977. "Richard Jones's Contribution to the Theory of Rent." *History of Political Economy* 9: 346–365.

Rashid, Salim. 1977. "William Whewell and Early Mathematical Economics." *The Manchester School* 45: 381–391.

Ricardo, David. 1951–73. *The Works and Correspondence of David Ricardo*. Edited by Piero Sraffa with the collaboration of Maurice H. Dobb. Eleven volumes. Cambridge: Cambridge University Press. (Cited as *Works* I–XI.)

Schumpeter, Joseph Alois. 1954. *History of Economic Analysis*. Oxford: Oxford University Press.

Theocharis, Reginos D. 1993. *The Development of Mathematical Economics*. London: Macmillan.

Thompson, T. Perronet. 1826. *The True Theory of Rent, in Opposition to Mr. Ricardo and Others, of Fallacies on Rent, Tithes, etc*. London: Effingham Wilson.

Whewell, William. [1859] 1964. "Prefatory Notice." In Richard Jones, *Literary Remains consisting of Lectures and Tracts on Political Economy of the late Rev. Richard Jones*. Edited with a Prefatory Notice by the Rev. William Whewell. New York: A. M. Kelley.

Whewell, William. [1862] 1967. *Six Lectures on Political Economy*. New York: A. M. Kelley.

Whewell, William. [1829] 1971a. "Mathematical Exposition of some Doctrines of Political Economy." *Transactions of the Cambridge Philosophical Society* 3 (1): 192–230. Reprinted in William Whewell, *Mathematical Exposition of Some Doctrines of Political Economy*, New York: A. M. Kelley, 1971.

Whewell, William. [1831] 1971b. "Mathematical Exposition of Some of the Leading Doctrines in Mr Ricardo's 'Principles of Political Economy and Taxation'." *Transactions of the Cambridge Philosophical Society* 4 (1): 155–198. Reprinted in William Whewell, *Mathematical Exposition of Some Doctrines of Political Economy*, New York: A. M. Kelley, 1971.

## APPENDIX: WHEWELL'S FALLACIOUS PRESENTATION OF JONES'S ARGUMENT

William Whewell, the polymath and master of Trinity College, took up Jones's argument in his *Six Lectures on Political Economy* (1967), in which he sought to disprove Ricardo's theory of rent by arguing that the rise of rents in England had not been caused by decreasing agricultural productivity but rather by the increased application of fixed capital.[19] Focusing attention on extensive differential rent, Whewell first showed by means of simple numerical examples that the expansion of output at the extensive margin of cultivation must increase rents both in absolute terms and as a share of national income (1967, pp. 62–64). This is so because the amounts of rent accruing on the better qualities of land must become an ever larger fraction of output when an inferior quality of land is brought under cultivation, and "therefore all the fractions at the latter stage, multiplied by their quantities, and added together, must be greater than at the former stage" (1967, p. 66).[20] Following Jones, Whewell then asserted that Ricardo's theory of rent implied that the rent share in total income must increase, and that this conflicts with the empirical record: "But in the progress of agriculture in England during the past century, it is allowed, by all those who have attended to the subject, that though the amount of rent has increased, the rent is now a smaller fraction of the gross produce than it was formerly" (1967, pp. 66–67).

How, then, to explain the rise of rent in absolute terms and its simultaneous fall in proportionate terms?

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[19]Whewell had also made an attempt to disprove Ricardo's theory of rent and agricultural improvements in his earlier papers on mathematical economics (1971a, 1971b). However, the analysis of agricultural improvements in his first paper was inspired by Perronet Thompson's objections to Ricardo's analysis (see Thompson 1826), and the following two papers, while taking up some of Richard Jones's ideas, do not specifically address the argument concerning fixed capital here under consideration. For assessments of Whewell's contributions to mathematical economics, see Brems (1970), Cochrane (1970, 1975), Rashid (1977), Campanelli (1982, 1998), Henderson (1973, 1975, 1985, 1996), and Creedy (1989).

[20]Whewell's proposition is explicitly based on the assumption that the land of the country consists of a *continuous progression of soils of decreasing fertility*. Therefore, Whewell cannot be accused of a "failure to recognise" that the rent share could diminish with a rising output, if a sufficiently large part of this output is produced on the marginal land, as Rashid (1977, p. 389) has claimed. If the marginal land is infinitely small, this is clearly not possible.

I reply, it is the use of *Auxiliary Capital*; that is, capital employed in machines, (ploughs, carts, &c.), manure, draining, working cattle, and all other contrivances by which the agricultural labour of man is assisted.

Now, how will this auxiliary capital affect the question of rent?

In this way. The capital thus employed is to a certain extent, fixed capital: that is, it lasts a certain number of years, and requires to be replaced only after that time. Thus a capital of £60 which wears out in ten years may be replaced by a return of £6 a year. Or rather, a capital of £50 which wears out in ten years may be replaced *with profits* by a return of £6 a year. Now, what will be the effect of such a capital on Rents? (Whewell 1967, p. 68)

In order to answer this question, Whewell provided two simple examples. Unlike Jones, he presented the argument explicitly in terms of agricultural improvements that become newly available (see examples 1 and 2 below). In both cases, a newly available fixed-capital-using method is supposed to increase the output on all types of land "somewhat in proportion to the original outputs" (reckoned in units of corn), giving rise to an increase of rent in absolute terms and a simultaneous decrease in the rent share:

Example 1:

| | Output on land of type | | | Gross produce | Rent | Rent share |
|---|---|---|---|---|---|---|
| | A | B | C | | | |
| Pre-improvement | 20 | 15 | 10 | 45 | $10 + 5 = 15$ | $\dfrac{15}{45} = \dfrac{1}{3}$ |
| Post-improvement | 28 | 22 | 16 | 66 | $12 + 6 = 18$ | $\dfrac{18}{66} = \dfrac{3}{11}$ |

Example 2:

| | A | B | C | Gross produce | Rent | Rent share |
|---|---|---|---|---|---|---|
| Pre-improvement | 20 | 15 | 10 | 45 | $10 + 5 = 15$ | $\dfrac{15}{45} = \dfrac{1}{3}$ |
| Post-improvement | 36 | 30 | 24 | 90 | $12 + 6 = 18$ | $\dfrac{18}{90} = \dfrac{1}{5}$ |

(Adapted from Whewell 1967, pp. 69–70)

Whewell concluded:

But all these numbers are hypothetical, and introduced merely for the sake of illustrating by example my proposition. The proposition is this: that rents may increase not only by the extension of cultivation to poorer soils; but also by improvement of methods of culture; and that the increase of produce and of rents in England has arisen from such improvement, much more than from the extension of culture to worse soils. (Whewell 1967, p. 71)

It should be clear that Whewell's numerical examples provide no disproof of Ricardo's propositions on the effects of agricultural improvements. Both focus on 'capital (alias labor)- saving' improvements (Ricardo's second type) and both lead to declining rents in absolute terms when the demand for agricultural produce is taken as given and unchanging (because land of type $C$ need not be cultivated any more in the post-improvement situation). Moreover, it is easily recognized that in both examples, Whewell's result has nothing to do with fixed capital, but derives from a combination of two specific assumptions. On the one hand, the improvements are taken to increase the output differentials between the different qualities of land, so that rents rise in absolute terms. On the other hand, the rent share happens to decrease in Whewell's calculations only because the improvements are supposed to increase the output obtained on the marginal land by a sufficiently large amount, so that the profits-and-wages share increases relative to the rent share.