

Representing the Production and Circulation of Commodities in Material Terms

On Sraffa's Objectivism*

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For it is ... the object of the present treatment ... to represent the production and circulation of commodities in material terms (i.e. quantities of labour, of commodities and periods of time) *independent of* the distribution of the product, i.e. of the rate of profit. (D3/12/27: 11)

* An earlier version of this paper was given on the occasion of the conference 'Piero Sraffa, 1898-1983', organised by the Istituto Italiano per gli Studi Filosofici in Naples, 9-11 October 2003. We are grateful to the participants at the conference for useful discussions and observations. We should like to thank Pierangelo Garegnani, literary executor of Sraffa's papers and correspondence, for granting us permission to quote from them. References to the papers which are kept at Trinity College Library, Cambridge, follow the catalogue prepared by Jonathan Smith, archivist. Unless otherwise stated, all emphases are in the original, where words or passages Sraffa underlined are italicised by us. Sraffa frequently abbreviated 'and' by '+'; we shall use the word instead of the symbol. Since in his texts Sraffa used both round and square brackets, all additions by us will be bracketed by { and }. We are grateful to Jonathan Smith and the staff of Trinity College Library for continuous assistance while working on the Sraffa papers. We received valuable comments on an earlier version of the paper from Tony Aspromourgos, Pierangelo Garegnani, Christian Gehrke, Geoff Harcourt, John King, Gary Mongiovi, Annalisa Rosselli, Bertram Schefold and Ian Steedman. It goes without saying that the responsibility for any errors and misinterpretations is entirely ours. We should like to stress that the views contained in this paper have not been discussed with the other participants in the project of preparing an edition of Sraffa's papers and correspondence we are involved in and therefore do not implicate them.

1. Introduction

It is a commonplace in the literature devoted to Sraffa's work to stress that whatever he put in print was generally the upshot of a long process of thinking and then of careful composing and writing. Without too much of an exaggeration it can be said that behind basically each and every sentence Sraffa published there is an amount of material available in his papers of at least the size of an essay or an entire treatise. Since the opening of Sraffa's papers his 1960 book (Sraffa, 1960) can be read against the background of the huge amount of preparatory material he had composed over a time span of more than three decades. The reader will discern in Sraffa's treatise numerous pointers to the literature where occasionally with a single word Sraffa relates a concept he adopts or a view he advocates to a particular historical debate, or a particular doctrinal point of view, or a particular author. *Production of Commodities by Means of Commodities* abounds with frequently subtle hints which will only gradually come to the fore as the complexity of Sraffa's contribution and the delicate communication between his published and unpublished work are laid bare.

As is well known, from an early time onward Sraffa was critical of the subjectivist element permeating much of contemporary theory and the corresponding concept of 'psychic costs' and in the late 1920s deliberately sought to elaborate an *objectivist* alternative to it revolving around the twin concepts of *physical real cost* and *social surplus*. The surplus refers to those amounts of the various commodities that obtain after the means of production and the means of sustenance in the support of the workers necessary to produce given outputs – their physical real costs – have been deducted from the latter. On the basis of these givens Sraffa then determined the general rate of profits (or interest), the rents of land, and the necessary prices corresponding to the given distribution of the product. This was the starting of Sraffa's constructive work and it will also be the starting point of our investigation. We then discuss important steps taken by him in the course of developing this basic idea, the problems he encountered and the ways in which he solved them.

The present paper elaborates on a piece we gave at a conference of the Charles Gide Society in Strasbourg in 2001 (Kurz and Salvadori, 2001). In the meantime our understanding of the issue has grown. However, in view of the amount and the complexity of the material in Sraffa's papers that is directly pertinent to our task, there is no presumption that the following will provide a complete or at least a well balanced picture of the case under consideration. No such claim is made. We rather felt the need to emphasize some aspects to the detriment of others. This is prompted by our own experience when studying Sraffa's papers. Sraffa in one

of his preparatory notes for his lectures on advanced theory of value composed in the summer of 1927 stressed that he was not giving to the discussion of questions an amount proportional to their importance, but rather, proportional to what one is 'likely' to have 'overlooked' when studying the subject (see D3/12/3: 69). The danger of not seeing, of setting aside and of neglecting important elements was also experienced by us with regard to Sraffa's paper. Overlooking such elements comes at a high cost: that of not understanding at all, or of misunderstanding. It was only in the course of a long and winded process of going back and forth between the papers, of trying to get their chronology right, of paying attention to the philological side of the problem, of looking up the sources Sraffa consulted, etc., that we gradually made progress. Arguments and ideas encountered in the papers which previously had totally escaped our understanding are now clear to us and others we believe to understand better. We do not claim, of course, to have 'solved' the problem or to have 'unveiled' all its fascinating detail. Far from it. However, we think that the evidence put forward, its chronology and underlying logical structure, and the elements highlighted ought to be taken into consideration in order to get a clearer picture of the intellectual path Sraffa followed and to avoid interpretations that are doubtful or outright wrong.

The lines serving as a motto of this paper are taken from a note Sraffa composed on 4 December 1942 titled 'Fixed into Circulating Capital' – *Objective basis*'. The note was written shortly after Sraffa had resumed the work on what was to become his 1960 book after a decade of interruption caused by his appointment to the editorship of the works and correspondence of David Ricardo (see Ricardo, 1951-73). The note rings in Sraffa's breakthrough with regard to a problem that had bothered him almost from the beginning of his constructive work in 1927 and had called in question the very foundation of his objectivist analysis: the problem of fixed capital. The latter had turned out to be a veritable touchstone to his 'classical' approach to the theory of value and distribution: Whereas in the case of circulating capital goods, such as raw materials, the process of value transfer to the product and the physical 'destruction' of the input are one and the same thing, in the case of fixed capital goods, such as machines, this is typically not so. The question then was whether in this case, as well as in general, production and circulation can be conceived of in purely 'material terms'.

Sraffa's consecutive attempts to show that this was in fact possible are the object of this paper. It is composed in the following way. In Section 2 we draw the reader's attention to Sraffa's interpretation of the classical economists; the emphasis will be on two elements – the twin concepts of physical real costs and surplus on the one hand and that of circular flow of production on the other – and the difficulties the classical authors encountered in bringing analytically to fruition these two elements. Section 3 deals with Sraffa's transition from the concept of given real wages conceived of as an inventory of commodities to that of given

proportional wages, to use Ricardo's term. This transition prompted Sraffa to reconsider, and eventually abandon, his earlier critical attitude toward the concept of labour as a 'quantity'. After having developed in 1931 a 'second way of approach' to the theory of value and distribution: the reduction to dated quantities of labour, the first being the method of simultaneous equations, Sraffa could then also decide precisely when the prices obtained by solving his equations were proportional to the quantities of labour embodied in the different commodities. Section 4 touches upon Sraffa's aim in the first period of his constructive work to elaborate an 'atomic analysis' shaped in no small degree by the natural sciences, especially physics. A characteristic feature of this phase of his work is that he was then intent to 'objectivise' all property incomes, interest (profits) and rents, by reducing them to some 'social' as opposed to 'natural' cost to be borne by workers. The reason for his eventual abandonment of a strictly science-based concept of objectivism is discussed in Section 5. Sraffa understood that, ironically, this concept could not do without 'allowing to come back through the window the "inducements" we had excluded from the door'. Section 6 then expounds why fixed capital was a formidable obstacle in the way of elaborating an objectivist (as newly defined) analysis and how Sraffa after some unsuccessful attempts finally managed to overcome it. Section 7 concludes.

2. Elaborating a 'physical real cost' theory of value and distribution

At the beginning of his academic career Sraffa appears to have adopted by and large the received Marshallian interpretation of the classical economists as early and rude type of demand and supply theorists, with the demand side still in its infancy (see Garegnani, 2004). However, he gradually learned that this implied a travesty of facts. The radical change of his view of the classical authors was not least the result of his reading, in the summer of 1927, of the French translation of Karl Kautsky's edition of *Theorien über den Mehrwert* (Marx, 1924-25) and then, of course, of his consulting the fonts – the works of Petty, Cantillon, the Physiocrats, Adam Smith, Ricardo, Torrens and others. What initially appears to have impressed Sraffa most with regard to these authors was their explanation of all incomes other than wages in strictly objectivist terms on the basis of the social surplus product. The objectivist orientation had found its perhaps clearest expression in a passage in William Petty's *Political Arithmetick* in which Petty advocated the "'physician's" outlook':

The Method I take to do this [i.e. political arithmetic], is not yet very usual; for instead of using only comparative and superlative Words, and intellectual Arguments, I have taken the course (as a Specimen of the Political Arithmetick I

have long aimed at) to express my self in Terms of *Number, Weight or Measure*; to use only Arguments of Sense, and to consider only such Causes, as have visible Foundations in Nature; leaving those that depend upon the mutable Minds, Opinions, Appetites, and Passions of particular Men, to the Consideration of others ... (Petty, 1691, Preface; emphasis added; see also Petty (1986), *Works*, I, p. 244; similarly in his *Political Anatomy of Ireland*, in *Works*, I, pp. 129-30; and D3/12/4: 3)^{1,2}

This was a starting point that met with Sraffa's approval, but was the method also feasible? Could a capitalist economy in conditions of free competition be at all analysed in these terms? Could the competitive rate of profits, the rents of land and relative prices be determined 'in Terms of Number, Weight or Measure' or did this approach amount to chasing a will-o'-the-wisp, as modern theory with its strong subjectivist element seemed to imply? Was not the replacement of the doctrine of the classical economists by that of the marginalists a clear expression of the fact that a strictly objectivist approach was impossible, and had such an approach not already come under attack at the time of the classicals? Could Petty's vision eventually be realised or had it to be relegated to the world of fiction?

At the time these questions were not easy to answer for Sraffa. First, in 1927 his knowledge of the classical authors, although swiftly growing, was not yet very advanced. Secondly, and notwithstanding what has just been said, it had not escaped his attention that the classical economists had not succeeded in elaborating a logically coherent theory of value and distribution in strictly objectivist terms. When confronted with difficulties beyond the analytical tools at their disposal they had recourse to means and ways that led them further and further away from their starting point. This consisted in the conviction, as James Mill had stressed, that man cannot create matter; man can only recombine and separate it, change its form and move it (see D3/12/10: 51). Production involves 'destruction', and the 'real cost' of a commodity – to

¹ In Sraffa's diaries the name of Petty appears for the first time on 27 November 1927 in a list of names containing also those of Adam Smith, the Physiocrats, Quesnay and Sismondi; see E1.

² Sraffa referred to a paper by Cunningham (1892) in which the latter defended Petty's approach against Marshall's description of 'economics as the science of measurable motives'. The former is said to lay 'a solid foundation of fact. ... But when we start from motives, we loose all this advantage. ... Motives are not obvious and we are likely to be mistaken about them.' See D3/12/9: 18.

use Marshall's term, from whose analysis Sraffa had started – consists in the commodities destroyed in the course of its production. According to the view that gradually took shape in Sraffa's mind the classical economists had essentially a concept of *physical real cost* (see the evidence collected in D3/12/42: 33-56; see also Garegnani, 2004). This concept, together with that of a physical surplus product, Sraffa was convinced, held the key to the problem of value. He stressed, 'the sort of "costs" which determines values is the collection of material things used up in production.' (D3/12/7: 106) While these costs could easily be ascertained with regard to circulating capital goods, for example, raw materials, things were different with regard to fixed capital and labour.³ As to labourers, Sraffa in the initial phase of his constructive work sided with Petty who had insisted that what matters are the means of subsistence in their support or, for short, 'food', not labour.⁴ He maintained: 'A. Smith and Ricardo and Marx indeed began to corrupt the old idea of cost, – from food to labour. But their notion was still near enough to be in many cases equivalent.' (D3/12/4: 2) Yet, small errors may grow into larger ones:

The fatal error of Smith, Ricardo, Marx has been to regard "labour" as a quantity, to be measured in hours or in kilowatts of human energy, and thus commensurated to value. ... All trouble seems to have been caused by *small* initial errors, which have cumulated in deductions (e.g. food of worker = quantity of labour, is *nearly* true). *Petty had foreseen the possibility of being misunderstood*, cfr. Marx, Hist., I, p. 1' (D3/12/11: 36; last emphasis added; similarly D3/12/4: 4)

In this early phase extending roughly from 1927 well into 1929 Sraffa was reluctant to speak of labour as a 'quantity' and variously called the concept 'metaphysical'. He insisted:

It is the *whole* process of production that must be called "human labour", and thus causes all product and all values. Marx and Ricardo used "labour" in two different senses: the above, and that of *one* of the factors of production ("hours of labour" or "quantity of labour" has a meaning only in the latter sense). It is by

³ A treatment of the problem of fixed capital has to wait until Section 6.

⁴ This was motivated in no small degree by a fact well known to Petty and the Physiocrats, namely, that in agriculture workers have to be paid even in periods when natural conditions prevent them from performing at all or at least from performing their normal tasks, such as in winter time. See Sraffa's respective observations in D3/12/12: 8.

confusing the two senses that they got mixed up and said that value is proportional to quantity of labour (in second sense) whereas they ought to have said that it is due to human labour (in first sense: a non measurable quantity, or rather not a quantity at all). (D3/12/11: 64)

Sraffa's critical stance at the very beginning of his constructive work towards the second sense in which the concept of labour was used is documented in many papers and notes composed in the late 1920s and in annotations in his books. Here a few examples must suffice. In his copy of the French edition of Marx's *Theorien* – the eight volumes of the *Histoire des doctrines économiques* – Sraffa noted carefully all passages in which Marx distanced himself explicitly from an approach to the theory of value that proceeds exclusively in terms of commodities or 'use values'. Right at the beginning of the *Histoire*, in volume I, Marx took issue with Petty who had singled out food, not labour, as the measure of value. In the margin Sraffa placed a wrinkled line along the passage in which Marx contended that any such physical input 'n'est pas la mesure immanente des valeurs' (Marx, 1924, vol. I, p. 3, fn).⁵ And in his own index of volume III Sraffa noted 'Quantités de produits (non de travail) comme mesure 278, 287-9, 306-7' (Marx, 1925, vol. III, fly-leaf at end of book). And then again, in volume VI, we find in Sraffa's own index the entry 'Marx against physical costs 122' (Marx, 1925, vol. VI, fly-leaf at end of book).

From this perspective it was also quite natural to question the special treatment of 'human labour' as opposed to other kinds of labour in several classical and also marginalist authors, especially Alfred Marshall. The latter had specified the 'keynote' of his *Principles* to consist 'in the fact that free human beings are not brought up to their work on the same principles as a machine, a horse, or a slave.' (Marshall, [1890] 1920, p. 504; similarly F. Y. Edgeworth: see D3/12/42: 36). Sraffa objected:

There appears to be no objective difference between the labour of a wage earner and that of a slave; of a slave and of a horse; of a horse and of a machine; of a

⁵ See also Sraffa's respective excerpts from the *Histoire* in D3/12/11: 88 and his quotation from Gentile (1899) in D3/12/10: 40: 'Il Feuerbach disse, come espressione ultima e tipica del suo materialismo: *l'uomo è nè più nè meno di ciò che mangia* (der Mensch sei nur das, was er esse).' In this context it should be mentioned that the name of the Young Hegelian and materialist philosopher Ludwig Andreas Feuerbach (1804-72) is mentioned in Sraffa's diary on 11 January 1928 together with that of the evolutionary philosopher Ernst Heinrich Haeckel (1834-1919).

machine and of an element of nature (?this does not eat). *It is a purely mystical conception that attributes to human labour a special gift of determining value.*
(D3/12/9: 89; emphasis added)

Sraffa's argument echoes a statement by John Ramsey McCulloch which had been criticised by Marx in the *Histoire* (Marx, 1925, vol. VII, pp. 22 and 24; see also Marx, 1972, p. 179). Sraffa did not agree with the criticism. In his own index of the volume he stressed: 'Sbagliata critica c.{ontra} {Mistaken criticism of} McCulloch 22, 24'. He also added the following reference: 'Smith appelle un boef {sic} un ouvrier productif {Smith calls an ox a productive labourer} 23'.

According to Sraffa, Petty and the Physiocrats not only had the right notion of cost; they also advocated a view of production which was congenial to modern industrial societies: They envisaged production as a *circular flow* rather than as a unidirectional sequence leading from the services of original factors of production via a series of intermediate products to final goods. The circular flow view was expressed most effectively by François Quesnay in the *Tableau Économique*. Sraffa paid tribute to the latter by equating his equations with it (see D3/12/16: 7). In a draft of parts of the preface of his book probably written in the 1950s he maintained that this point of view 'implies replacing the notion that "commodities are produced by factors of production" with the other that "*commodities are produced by commodities*"', which in turn amounted to 'replacing the idea that the process of production has a beginning and an end with that that it is a circular one – an idea first introduced by the *Tableau économique*.' (D3/12/7: 2; emphasis added)

The perplexing formulation that 'commodities are produced by commodities' can in all probability be traced back to Sraffa's reading in early 1932 of the third edition of James Mill's *Elements of Political Economy*. Mill had maintained:

The agents of production are the commodities themselves They are the food of the labourer, the tools and the machinery with which he works, and the raw materials which he works upon. (Mill, 1826, p. 165, emphasis added; see also Sraffa's excerpts in D3/12/9: 106-118)

When in the second half of the 1950s, the third period of his constructive work, Sraffa began to put together his book, for a while he thought of giving it the title 'Outline of an Economic

System, or, The Production of Commodities by Commodities' (see D3/12/80: 2), echoing Mill's formulation.⁶

However, in the end he decided against this title for reasons which comprise probably also the following two. First, while the title would have been appropriate as long as wages are given in physical terms, that is, as an inventory of well specified quantities of particular commodities distributed to the workers at the beginning of the production period in order to 'enable' them to work, things are different in the case in which workers participate in the surplus product. Whereas in the former case wage costs consist of a fixed vector of amounts of commodities, in the latter they can only be given in terms of some more or less abstract standard. Relatedly, while in the former case it is natural to consider wages as paid at the beginning of the production period, in the latter it is almost equally natural to consider them as paid at its end, when the surplus product is already in place (see on this Sraffa, 1960, pp. 9-10). Since only §§ 1-8 of Sraffa's book involve a given inventory wage (paid *ante factum*), the title under consideration could easily be considered somewhat misleading. Secondly, Sraffa was very concerned that his book would not be put on one side because of some avoidable misunderstanding or formulations that might antagonise the reader. Since the training of most economists was marginalist, based on an entirely different concept of 'agency' and a subjectivist outlook on economic phenomena, the title under consideration might have been regarded as repulsive by some of the potential readers of the book and its author might have been branded a crank. However, despite his decision against the title the fact that Sraffa considered it eligible until the very last instant shows how much he felt that it conveyed an important message of the book.

The question was: What were the main reasons why the classical economists had failed to elaborate a consistent theory of value and distribution on the basis

- (a) of production viewed as a circular flow and
- (b) of the twin concepts of physical real costs and social surplus?

Here we focus attention on one of the reasons which Sraffa variously expressed as consisting in a mismatch between analytical concepts on the one hand and the tools available to deal with

⁶ It is also interesting to note that when Sraffa received the galley-proofs of his book (which had first been corrected inhouse by Cambridge University Press), he would note in his diary on 26 September 1959: 'Ricevuta 1^a bozza corretta completa di "P. of C. by C." {Received the first corrected complete proofs of "P. of C. by C."}'

them on the other. More specifically, as Sraffa had demonstrated as early as November 1927 with his first equations devoted to the case of an economy without a surplus, the tool needed in order to bring to fruition one with another conceptual elements (a) and (b) were simultaneous equations and the knowledge of how to solve them and what their properties are. As Sraffa stressed in a document written in all probability in late 1927 or early 1928, 'the fundamental force is physical real cost' which, however, is 'seen only in general equilibrium.' (D3/12/42: 46)⁷ The indispensable tool – simultaneous equations – alas! was not at the disposal of the classical authors and Marx who therefore tried to solve the problems they encountered in a roundabout way, typically by first identifying an 'ultimate standard of value' by means of which *heterogeneous* commodities were meant to be rendered *homogeneous* (in some dimension). Several authors, including Smith, Ricardo and Marx, had then reached the conclusion that 'labour' was the sought standard and had therefore arrived in one way or another at some version of the labour theory of value. This was understandable in view of the unresolved tension between concepts and tools. However, it was far from clear where the labour values came from and how they could be ascertained. There was no reason to presume that they could be known independently of solving a system of simultaneous equations. Hence the route via labour values was not really a way out of the impasse in which the classical authors found themselves: it rather landed them right in that impasse again. Commodities were

⁷ It had not escaped Sraffa's attention that Vilfredo Pareto (and, following him, also Francis Y. Edgeworth) had criticised earlier authors for treating as givens what had to be considered as unknowns in the theory of value: Pareto's focus were especially the wage fund theory, the labour theory of value, cost of production theories and the Austrian theory. Sraffa had carefully studied several of Pareto's contributions at an early time which is reflected in many annotations in those that are in his library and in several references to Pareto in his early papers; see, in particular, Pareto (1901, 1902a, 1902b, 1906). On 11 January 1928 we find in Sraffa's Cambridge Pocket Diary next to the names mentioned in footnote 5 also the remark: 'Par. systemes, II, 288, G. E. Set 1901'. There can be no doubt that this is a reference to p. 288 of vol. II of Pareto's *Les systèmes socialistes* (Pareto, 1902a) and a paper published by Pareto in the September issue of 1901 of the *Giornale degli Economisti* (Pareto, 1901). (The latter paper is referred to in Pareto, 1902, p. 287.) On the page mentioned Pareto deals with the necessity to determine (relative) prices in terms of simultaneous equations and introduces his criticism of the older economists who did not have this tool at their disposal and tried to simplify matters by taking a sufficiently large number of the variables under consideration as known magnitudes.

produced by means of commodities and there was no way to circumnavigate the simultaneous equations approach.

Before we proceed, we must address the question when and why Sraffa changed his original view concerning labour as a quantity and its role in the theory of value and distribution.

3. 'Proportional wages' and labour as a quantity

We have seen that initially Sraffa did not consider labour as a 'quantity', a measurable magnitude, at all; he rather took the concept to represent the production process as a whole (see D3/12/11: 64-65). Labour in this latter sense was needed as much as all the use values entering into production. Seen in this way, 'all values are "due" to labour, or to wheat or to any other thing that enters in the production of every {one} of them.' (D3/12/10: 71) In this period Sraffa showed little interest in the labour theory of value or in Marx's 'transformation' of labour values into prices of production. He considered these attempts as misled and misleading. He acknowledged, though, that the labour theory of value (just as the theory he was about to elaborate) tried to preserve an objectivist character by taking as data, or known quantities, only measurable things, such as amounts of commodities actually produced and amounts actually used up, including the means of subsistence in the support of workers.⁸ (This distinguished such a theory from marginalism in its various forms, all of which have recourse to subjective elements.) He initially disputed, however, that labour belongs to the set of measurable things.

Sraffa could avoid the concept of labour as a quantity as long as his own analysis was confined to the study of cases in which the remuneration of workers was given in physical terms – as an 'inventory' of wage goods to be consumed by workers (and their families) in order to enable them to perform their tasks in production. In this case that part of the physical real cost of producing a particular commodity that represented Petty's food was well defined. There was no need whatsoever to introduce the concept of labour as a magnitude on which to base the theory of value. This case underlies Sraffa's first and second equations. Yet what if workers participate in the surplus product, if wages are higher than what is needed for mere subsistence? This case had already been studied by Ricardo and had made him establish the inverse

⁸ As Sraffa noted in a document to which we will refer again in the following section: "The "extensive" theory of rent, and the labour theory of value only assume this kind of knowledge.' (D3/12/13: 2)

relationship between wages and the rate of profits. Sraffa turned to this case in the summer of 1928 when he began to investigate the impact of an increase of wages on the rate of interest and relative prices in what were his 'third equations'. Apparently Sraffa's treatment of the problem was inspired by Ricardo's respective investigation. In order to be able to cope with the case in which wages exceed mere sustenance, Ricardo had introduced the concept of 'proportional wages' conceived of as the portion of any given annual value of the net product (in terms of labour values) paid to the labouring class (see Ricardo, *Works*, vol. I, p. 420).

In accordance with his material or use value-based approach, Sraffa at first studied the problem in terms of a straight re-distribution of the physical surplus of a system that is in a self-replacing state away from profits to real wages: whichever fraction of the surplus consumed by the capitalists as luxuries is taken away from them is directly allotted to workers (see the equations and discussion in D3/12/7: 63 and 93). Hence, as regards the surplus component of wages, workers are taken to consume the same commodities in the same proportions as capitalists. Because of this construction, any physical re-distribution involves at the same time a change in the *share* of wages in the surplus that is independent of the prices of commodities. While this procedure translated Ricardo's labour-based reasoning into a physical one, it could not satisfy Sraffa. First, there was no reason to presume that workers would spend their wages over and above sustenance exactly as capitalists spent profits. Secondly, there was no presumption that with higher wages workers would still consume the subsistence quantities of commodities. Apparently, no such assumptions were implied by Ricardo's concept of proportional wages or – as Sraffa swiftly noted – Marx's equivalent concept of the rate of surplus value, which therefore deserved closer scrutiny. As a consequence of it toward the end of the first period of his constructive work he adopted a version of the Ricardo-Marx concept (see also Gehrke, 2003, and Gehrke and Kurz, 2004).

In view of the need to elaborate a concept of wages congenial to the case under consideration workers could obviously no longer be represented in the equations of production in terms of the smaller or larger quantities of food at their disposal: the concept of real wages conceived of as an inventory of commodities was obsolete, a share concept had to be put in its place. Since wages were paid in relation to the work performed by workers, Sraffa eventually convinced himself that labour had to be treated as a measurable quantity. While soundings of doubts concerning his earlier view can be traced back to mid 1929 (see, in particular, his notebook D3/12/12) it appears to have been only from around the turn of 1929 that he gradually changed his view in this regard and began to consider human labour both as quantifiable and as to be distinguished from other kinds of labour. He now assumed that wages were paid in proportion to the labour performed and we encounter equations in which the quantity of labour employed in industry i , L_i , is explicitly given (see D3/12/7: 166 and 159 (1)). In 1931, at the latest, he

also adopted for good the concept of wages as a share. However at first and in accordance with Ricardo (and actually up until late 1943) he retained the assumption of wages paid at the beginning of the period of production and thus belonging to the capital advanced. Yet he deviated from Ricardo's approach by not measuring wages as a portion of total labour performed during a year going to workers, but rather as workers' share in the value of net product (defined inclusive of total wages); see, in particular, several documents in folder D3/12/7 (especially 159 and 168-9) written in the second half of 1931.

Sraffa's new view of human labour and its remuneration also necessitated a reconsideration of its characteristics compared with those of the other kinds of labour. Whereas the amount of fodder given to a horse, for example, is decided exclusively by its owner on grounds of economy, the wages paid to workers is the outcome of a bargaining process between capital owners and workers (see, for example, D3/12/42: 35). Sraffa also came across Ricardo's characterisation of machines as 'mute agents of production'. In a manuscript written in 1942, he expounded that in his first and second equations the 'food and sustenance of the workers {are} treated ... on the same footing as that of horses.' He added with characteristic irony: 'Men however (and in this they are distinguished from horses) kick.' (D3/12/16: 18)⁹

Accepting the idea that human labour can be conceived of as a measurable magnitude and has to be treated differently from other kinds of labour is one thing, to reach clarity as to whether and when the labour theory of value applies, and when not, is another thing. When discussing the impact of a change in wages on the rate of interest and relative prices in his third equations Sraffa saw that solving them for each and every level of wages was cumbersome and the results obtained not very transparent. He was therefore on the lookout for a 'second way of approach' (D3/12/9: 17) which was to render the properties of the economic system under consideration more easily accessible. He found it, first, in the method of reducing prices to dated wages or rather quantities of 'food'. This method he had already employed with regard to his first or without-surplus equations, reflecting his original concern with the concept of an 'ultimate standard of value'. However, once he had accepted labour as a quantity which could be taken as a 'constant' in economic theory, he could replace this earlier method with that of reducing prices to dated quantities of labour. This transition took place in 1931; see, especially, D3/12/7:

⁹ Interestingly, in the document referred to he went on: 'The horse (or his physiology) takes a strictly private view of his relation with his food, and does not allow any extraneous consideration to interfere: he is a perfect utilitarian and thus forms the ideal object of study of the marginal utility economist.'

158. And it seems to have been only after he had fully grasped the relationship between what he called 'my two ways of approach' (ibid.) that he also understood that in particular situations, especially the one in which the entire surplus went to workers and profits were nil, solving the system of simultaneous equations gives relative prices that are proportional to the relative quantities of labour obtained by summing all the direct and indirect labour terms contained in the reduction series relating to the different commodities. Hence it was only subsequent to introducing the second way of approach that Sraffa eventually found himself capable of deciding *precisely* whether and when the labour theory of value applied, and when not. He now could not only say 'that *all* values are "due" to labour', but rather that with a zero rate of interest values were strictly proportional to the quantities of labour 'embodied' in the different commodities. This is why, shortly after the resumption of his work in 1942, he suggested that we talk not of the labour theory of value, but of the 'Value Theory of Labour' – a particular solution of given production equations among many other possible solutions (see, for example, D3/12/44: 3 and D3/12/46: 24).

To conclude, it deserves to be mentioned that an important problem related to the labour quantity concept played no prominent role in the first period of Sraffa's constructive work: labour heterogeneity and how to render hours of qualitatively different labour commensurable. As is well known, Smith and Ricardo had suggested to 'reduce' different kinds of human labour to a single kind in terms of wage differentials (see Kurz and Salvadori, 1995, ch. 11). Sraffa adopted this procedure which had also been advocated by Marx as the following statement Sraffa excerpted from volume VI of the *Histoire* showed: 'le salaire serait l'index de la quantité total de travail {the wage will be the index of the total quantity of labour}' Marx (1924-25, vol. VI, p. 241); see D1/91: 59. This reduction device we encounter again in § 10 of Sraffa (1960, p. 10).

4. Seeking an 'atomic analysis'

The 1920s were a period in travail, politically, economically and scientifically. World War I, the Russian revolution and fundamental developments in the sciences had shaken up received views and generated the need for new orientations. Was socialism a feasible alternative to capitalism? Were there signs of convergence of the sciences, as Whyte (1928) had contended,

and would this convergence also involve the social sciences, especially economics?¹⁰ What did the latest findings in the sciences mean for mankind and its future? Did they contribute to a better understanding of the world and the options available to humanity and thus open new vistas on a more peaceful and just society? Was mankind standing at the eve of a new epoch? Titles of books such as *Science and the Modern World* (Whitehead, 1926) reflect the focus of a vibrant contemporary debate which, not surprisingly, did not come to a standstill at the gateways to economics. 1924 saw the publication of *The Trend of Economics*, edited by R. G. Tugwell, which carries papers by leading American economists, including F. H. Knight and J. M. Clark. It was designed to redefine the role of economics vis-à-vis the two main challenges of the time: socialism and the revolution in our understanding of physical processes and beyond. Sraffa read the book, annotated it carefully and referred to it repeatedly in his papers (see, in particular, folder D3/12/11, dated November 1927). Knight, for example, denied that it was possible 'to construct in thought a world of real objects in purely objective terms' and that human phenomena were 'amenable to treatment in accordance with the strict canons of science'? (Knight, 1924, pp. 242 and 251) According to him 'it is impossible to discuss value in purely objective terms' (ibid., p. 229). Sraffa's annotations indicate that he did not agree with Knight and rather sided with some of J. M. Clark's statements who advocated a fundamentally different point of view.

The question is close at hand: What exactly did Sraffa mean by an objectivist theory of value and distribution and was his view related in any way to the contemporary debates triggered by the sciences? This question has up until now never been raised, let alone answered. However, there is reason to think that an answer to it is of considerable importance for an understanding especially of the beginnings of Sraffa's constructive work in the late 1920s and early 1930s. In this paper we can provide only a few hints which hopefully will direct attention to this aspect of his work. Before we proceed, let us immediately stress that according to our reading of Sraffa's papers and the sources he consulted his concept of objectivism changed over time. We may distinguish broadly between two conceptualisations, one belonging to the first period of his constructive work up until August 1931, the other belonging to the time thereafter. In this section we report briefly on the former.

¹⁰ The possibility of a re-integration of the scientific disciplines had already been foreseen by Engels in *Socialism. Utopian and Scientific* (Engels, 1892), which Sraffa had read and annotated. Sraffa for a while appears to have been fascinated by the idea.

One encounters the first concept of objectivism in Sraffa's papers in characterisations of his own work as being concerned with establishing 'an entirely objective point of view', 'this natural science point of view' or, *tout court*, 'an atomic analysis' (see D3/12/7: 161 (3) and D3/12/13: 16 (9), 18). At the time Sraffa appears to have been convinced that in order to free economics from ideological contamination and to put it onto a solid basis two things were necessary: First, one had to go back to its beginnings, to the purity of its roots, where manifestations of fresh and impartial analysis could be expected. Second, one had to take into account major findings of the sciences, especially physics, because as it was ultimately concerned with the material process of human production, economics had to respect the laws governing the physical and chemical world. Also, in a long struggle the sciences had managed to largely escape from the spell of ideologies and were therefore a more reliable guide to an understanding of an important fact which in Sraffa's view Petty and the Physiocrats had put into sharp relief: the material foundations of human society. This is reflected in Sraffa's keen interest in the latest developments in the sciences, especially quantum physics and thermodynamics. Here is not the place to provide a detailed account of Sraffa's respective readings and how he absorbed them in some of his work. This is too big a task for the present paper and ought to be investigated in some depth. Here a few observations must suffice.

The attentive reader of Sraffa's unpublished papers might be surprised by some of the terms Sraffa used in defining his own approach to the theory of value and distribution. The reader's surprise can only be enhanced when he encounters in Sraffa's papers references to books on modern physics, chemistry or biology.¹¹ Finally, when consulting the huge library Sraffa bequeathed to Trinity College the reader will find a large number of books devoted to the sciences, many of which are heavily annotated by Sraffa and referred to in his papers.

Sraffa studied intensively Jules Henri Poincaré's *La Science e l'Hypothèse* (1902). From his annotations relating especially to chapter VIII, 'Énergie et Thermodynamique' (see Sraffa 3137), we can infer that in his view an objectivist approach in any of the fields of natural philosophy had to take into account the principles of thermodynamics. He read and took excerpts from Heinrich Hertz's *Principles of Mechanics* (1899), focusing attention on the

¹¹ Sraffa also studied some of the latest contributions to anthropology, in particular the works of B. Malinowski and R. M. Firth. Here his interest was to what extent and how a person's mind and behaviour were shaped by institutions, conventions, rules and the historical conditions of production, and what these disciplines had to say about the key figure of marginalism, *homo oeconomicus*. (See, for example, D3/12/7: 11.)

physicists' concepts of 'cause' and 'interdependence', and their corresponding role in economic theory, and on the problem of which kind of 'quantities' could in principle be taken as given in order to determine some other quantities (see D1/9: 8-10). These considerations find an echo in a document presumably written in the second half of 1929 in which Sraffa specified those 'quantities {that} have an objective, independent existence at every or some instants of the natural (i.e. not interfered with by the experimenter) process of production and distribution; they can therefore be measured physically, with the ordinary instruments of measuring number, weight, time, etc.' He stressed: 'These are the *only* quantities which must enter as constants in economic theory, i.e. which can be assumed to be "known" or "given".' (D3/12/13: 2)¹²

On 9 December 1927 we find in Sraffa's Cambridge Pocket Diary of 1927-28 a reference to L. L. Whyte's *Archimedes or The Future of Physics* (Whyte, 1928). The grand theme of Whyte, expressed in terms of the title of chapter I of his book, was whether 'The Sciences Converge'. Whyte saw reason to assume that the answer was in the positive. He wrote:

Physics, biology, and psychology are converging towards a scientific synthesis of unprecedented importance, whose influence on thought and social custom will be so profound that it will mark a stage in human evolution. ... For their researches on matter, life, and mind are now overlapping at one common issue: the nature of the fundamental electrical processes which underlie radiation and chemical combination. (Whyte, 1928, pp. 9-10)

While there is no reason to presume that Sraffa shared Whyte's thesis, there are indications that he did not regard it as bogus. A main theme in Whyte's book is the question of whether the elementary processes in nature are reversible. Sraffa referred to it in his discussion in the winter of 1927-28 of whether the process of production is reversible. He concluded that it depends on the point of view taken. If we consider single processes each one of them does not seem to be reversible. 'If we consider the aggregate of industry as a whole, however, reversion will be possible.' He concluded, taking into consideration also the circulation and exchange of commodities: 'The difference between production and exchange is thus twofold: that the first implies lapse of time and the second does not; that the latter involves dealing with other industries and the first does not.' (D3/12/5: 5 and 4)

¹² Interestingly, in the document referred to Sraffa still showed some vacillation whether to include labour among the quantities so specified.

Sraffa read and annotated A. S. Eddington's 1927 'Gifford Lectures' on *The Nature of the Physical World* (Eddington, 1928). In April 1928 he studied meticulously and annotated vigorously A. N. Whitehead's *Science and the Modern World* (Whitehead, 1926).¹³ Several of the themes dealt with by Whitehead (and other natural scientists) recur in Sraffa's early papers. They include, for example, Francis Bacon's appeal to 'efficient causes' as against 'final causes';¹⁴ the problem of a discrepancy between a conception and the technique to express it: according to Sraffa classical economics was possessed of essentially sound conceptions, but suffered from a 'primitive, rudimentary technique', whereas marginalist economics suffered from dubious conceptions, but was possessed of a 'refined' and 'highly perfected' technique (see D3/12/4: 10); the concept of time and that of dynamics: whereas classical economics treated the problem of value and distribution with regard to a self-replacing economic system and thus in an essentially timeless framework, marginalist economics with its stress on incremental change and movement requires time; and the problem of whether 'the whole is constitutive of the part', a view entertained by Sraffa (in accordance with Whitehead, and also the classical economists and Keynes), or *vice versa*, the view entertained by neoclassical economists.¹⁵

Judging from Sraffa's annotations, he apparently agreed to a large extent with what Whitehead had to say on the success of science since the seventeenth century: 'Science was becoming, and has remained, primarily quantitative.' Whitehead had added: 'Search for *measurable elements*

¹³ Whitehead's book is mentioned at the end of Sraffa's diary of 1927-28 (E1).

¹⁴ Starting from Whitehead, Sraffa expounded with regard to the different points of view of classical and marginalist theory: "Efficient causes" are facts of the past that act on the present: "final causes" are facts of the future that act on the present. The existence of the latter is at best dubious and they are better called "illusions". The classical P. {olitical} E. {conomy} dealt only with the first sort of causes, i.e. of "material things" that have existed in the past. Modern economics deals with the second class, i.e. hopes for the future, such as utility, abstinence, disutility, etc.; these things, it must be noticed, refer only to the foresight of *future acts*.' (D3/12/10: 61 (1))

¹⁵ In his essay on Edgeworth Keynes stated: 'Mathematical Psychics has not ... fulfilled its early promise. ... The atomic hypothesis which has worked so splendidly in physics breaks down in psychics. We are faced at every turn with the problems of discreteness, of discontinuity – the whole is not equal to the sum of the parts' (Keynes, 1933, *CW*, vol. X, 1972, p. 262). See also Sraffa's annotation of Labriola's assessment: 'L'Economia ci rivela la Società nell'Individuo non l'Individuo nella Società' (Labriola, 1922, p. 40).

among your phenomena, and then search for *relations between these measures of physical quantities.*' (Whitehead, 1926, pp. 63-4)¹⁶ This is an excellent description of what Sraffa started doing in terms of his systems of equations elaborated from the autumn of 1927 onwards.

Whitehead's lectures were explicitly designed to give 'the outline of what I consider to be the essentials of an *objectivist philosophy* adapted to the requirement of science and to the concrete experience of mankind.' (Ibid., p. 124; emphasis added) This must have been of particular interest to Sraffa with his materialist point of view developed *inter alia* in long discussions with his friend Antonio Gramsci in Italy. Yet Sraffa did not agree with Whitehead's claim that 'a thoroughgoing evolutionary philosophy is inconsistent with materialism' (ibid, p. 151), as he generally felt that Whitehead's concept of 'materialism' was too narrow and too much focused on obsolete orthodox materialism.¹⁷

Sraffa also showed a particular interest in quantum theory championed by physicists such as Werner Heisenberg, Erwin Schrödinger and Paul Dirac. He excerpted the following passage on Werner Heisenberg from an essay on 'The quantum theory' by H. S. Allen published in *Nature* in 1928:

Heisenberg put forward the demand that only such quantities as are observable should be represented in the mathematical formulation of *atomic theory*. ... This led to the development of the matrix mechanics, every term in a matrix corresponding to something which is, at least ideally, observable.' (Allen, 1928, p. 891; emphasis added. Cited in D1/9: 13; see also item 3204 of Sraffa's library, p. 35.)

¹⁶ See also Sraffa's following excerpts from Hertz (1899, pp. 1 and 23): 'We form for ourselves images or symbols of external objects; and the form which we give them is such that the necessary consequents of the images in thought are always the images of the necessary consequents in nature of the things pictured.' And: 'We are justified in deciding that *if our images are well adapted to the things, the actual relations of the things must be represented by simple relations between the images.*' (D1/9: 9; emphasis added)

¹⁷ Sraffa also disagreed with Whitehead's characterisation of post-Smithian political economy as having 'de-humanised industry' (Whitehead, 1926, p. 158). On the inside back cover of his copy of the book he accused Whitehead of 'sentimentalism'.

Sraffa read and annotated P. W. Bridgman's *The Logic of Modern Physics* (Bridgman, 1927) and referred to it in his papers. Quantum theory can be said to have brought about the greatest revision of thinking about the nature of the physical world since the days of Isaac Newton and constituted a revolution in our understanding of physical processes and beyond. What was to be learned from it in economics and did this have implications for the received marginalist doctrines?

On the constructive side, the late 1920s and early 1930s see a Sraffa at work intent upon laying a solid foundation of fact for each and every economic magnitude and variable under consideration. He despised subjectivism with its emphasis on psychic cost and attempted to put in its place an objectivist approach. This science point of view is reflected in an aspect that shapes much of his thinking at the time: Not only with regard to economic systems without a surplus but also with regard to systems with a surplus, Sraffa was keen to stay analytically within the realm of 'necessities' – to find sufficient reason for each and every phenomenon under consideration – a concern which can be said to be a characteristic feature of Sraffa's analytical efforts in the first period up until August 1931. He thought this could be accomplished by reducing the surplus – distributed in the form of interest or rent – to some 'cost' or other. In this way he felt to be able to carry over the concept of 'absolute value' developed for the without-surplus economy to the with-surplus economy.

Why is rent paid to landowners, why interest (profits) to capital owners? Could these property incomes be conceived as reflecting some *objective necessity*, rooted in some objective 'social' as opposed to 'natural' obstacles, which have to be overcome by workers, and if yes, which?¹⁸ Sraffa saw quickly that any attempt in this direction led ultimately back to the concept of 'inducement'. In a note of November 1927 he stressed: 'Cost in the sense of *Inducements* belong to *institutional economics*, they vary according to "social standards"' (D3/12/11: 98) And: 'incentive implies free choice, voluntary acceptance or refusal: and this implies in the factor of production the possibility of an *alternative* use, or of no use at all.' (D3/12/4: 5 (1-2)) Interpreting socially necessary inducements as social obstacles to production thus involved an investigation of the choices available respectively to workers, landlords and capitalists.

With the assumption of subsistence wages, reflecting some 'physiological laws that cannot be changed' (D3/12/7: 42), there is not really a question of 'incentive' with respect to workers:

¹⁸ See his statement: 'Interest appears thus as the necessary means of overcoming an obstacle to production. It is a social necessity as distinguished from the material necessity of, say, putting coal into a locomotive that it may do its work.' (D3/12/18: 11)

they must work in order to survive, and they are 'enabled' to do so by consuming. Otherwise their working capacity would be 'withdrawn'.¹⁹ Things are different with regard to the other two classes of society, and the question was, can rent and interest be conceived of as some 'necessary cost', can property incomes be subjected to some 'objectivisation' (D3/12/7: 46).²⁰ This led Sraffa to ask, in modern parlance: What is the reservation price of the use of the respective factor of production landlords and capital owners control? Could landowners 'withdraw' their land and capitalists their capital? Obviously, individually each landowner and capitalist could sell his entire property and use the proceeds to buy consumption goods. However, collectively, as a class, landowners cannot 'consume' their land. The landlord, Sraffa maintained, 'has no alternative use {for his land}, therefore no inducement is required because he makes no sacrifice, and therefore "rent does not enter into cost of production.{"}' (D3/12/4: 5 (2)).²¹ This is to say, the reservation price of the use of land is zero, a premise implicit in Ricardo's doctrine.²²

Capitalists, on the contrary, could collectively 'withdraw' their capital by converting it back into revenue and then consuming it. At once, however, only the circulating part of capital including forgone re-investment could be so converted, or, as Sraffa stressed with regard to a numerical

¹⁹ Things are actually not quite so simple as Sraffa stressed in a note of December 1927 on the breeding of children, married men, bachelors and family allowances (see D3/12/10: 65).

²⁰ The concept of objectivisation, or 'objectivation', was also used in the sciences. According to Schrödinger, 'two general principles ... form the basis of the scientific method, the principle of the understandability of nature, and the principle of objectivation.' (Schrödinger, 1944, p. 117)

²¹ As Sraffa noted (D3/12/7: 18), this view was expressed already in 1821 by an anonymous author in a critical disquisition on Malthus's doctrine (see Anon., 1821; see also D3/12/8: 10). Sraffa appears to have borrowed the terms 'withdrawing' and 'inducing' from the author whose pamphlet Marx in *Theorien über den Mehrwert* had dubbed 'one of the best of the polemical works of the decade' written by a Ricardian (see Marx, 1972, p. 117). Sraffa, in vain it seems, tried to discern who the author was. There is, however, evidence that it was not Samuel Bailey, as has variously been contended.

²² Again, things are not so simple, as Sraffa pointed out elsewhere, because there are, of course, alternative uses of land.

example, capitalists 'can only menace to "destroy" 10%' of their capital during the year (D3/12/4: 1(2); similarly D3/12/5: 16). It is therefore only this part of capital which is said to give the capitalists the power to demand the payment of interest, and interest should accordingly be reckoned *only* on circulating, *not* on fixed capital.²³ It should be stressed that Sraffa's argument related exclusively to inducements considered necessary to prevent any (net) dissavings or 'the non-destruction of the present stock of capital' (D3/12/10: 17), and not inducements necessary to generate (net) savings. Sraffa concluded: The resulting 'absolute values *with* surplus are no more what is necessary to *enable* to produce {commodity} A, but what is necessary to *induce* to produce A' (D3/12/6: 10).²⁴ He stressed that in this kind of explanation interest was due to the capital owners' 'failure to wait' (D3/12/42: 34) and *not*, as in received 'abstinence' and 'waiting' theories, in their actual abstinence or waiting.

The idea of interest as a 'social cost' (or 'obstacle') that has to be incurred (or overcome) by workers in addition to the 'natural' costs (or obstacles) recurs in many of Sraffa's early papers and notes. In early 1928 Sraffa expressed the idea by adding a further equation to his usual set of second equations (see D3/12/8: 29). The new equation was to represent a fictitious industry

²³ In this regard Sraffa also appears to have been partly inspired by Anon. (1821, p. 106) who had stressed that 'machines are like land; and owing to it, both must submit to take whatever they can get.' (See D3/12/7: 18.)

²⁴ A large part of Sraffa's early notes on fixed capital concern exclusively the case of seed, where by seed he generally meant the input of a commodity into its own production, viz. the use of seed corn to produce corn, but also, for example, the input of iron in the production of iron. Sraffa endorsed Smith's view that 'No fixed capital can yield any revenue but by means of a circulating capital' (WN, II.i.25). There is no space to provide a detailed account of why Sraffa at first, in 1927, accepted the 'seed' concept of fixed capital, but already a few months later, in 1928, rejected it (see, therefore, Kurz 2003). Here it must suffice to observe that initially Sraffa saw reason not to reckon interest on the input of a commodity used in its own production, i.e. seed, since 'seed does not enter into exchange, and its value is never determined: and since it is only through exchange{,} not through production{,} that individuals get hold of the surplus, no surplus is to be got from seed' (D3/12/6: 18). In early or mid 1928 Sraffa abandoned his previous view as to the non-payment of interest on seed and fixed capital. He saw that the premiss on which it rested was unfounded, namely, that this would not endanger the self-replacement of such capital items and, as a consequence, that of the system as a whole (see D3/12/9: 11).

that transforms the surplus quantities of the commodities produced by the other industries as a whole into a (composite) 'luxury', or 'gioelli', as he called the product elsewhere. The latter is not used as a (direct) input in any of the other industries. Its role in respect of the self-replacement of the economic system is only indirect: it is taken to 'induce' capitalists, via the consumption of the luxury, not to decumulate their circulating capital. In this way the surplus is tucked away: it 'disappears' or 'melts away', as Sraffa was to observe in a document to which we now have to turn. The document heralds an important change in Sraffa's concept of objectivism and the 'economic field' he sought to explore.

5. Criticizing an application of the principle of sufficient reason

As has already been indicated, it did not escape Sraffa's attention that by reducing profits (and rents) in the way suggested 'we are allowing to come back through the window the "inducements" we had excluded from the door' because of their subjectivist and psychological nature (D3/12/6: 10). This led Sraffa to some epistemological and methodological reflections which culminated in a piece written in August 1931 titled 'Surplus product'. In it Sraffa expounded why his science conceptualisation of objectivism had to be abandoned and what other conceptualisation was to be put in its place:

If one attempts to take an entirely objective point of view, the very conception of a surplus melts away. For if we take this natural science point of view, we must start by assuming that for every effect there must be sufficient cause, that the causes are identical with their effects, and that there can be nothing in the effect which was not in the causes: in our case, there can be no product for which there has not been an equivalent cost, and all costs (= expenses) must be necessary to produce it.

The conception of 'necessity' has to be extended to everything that happens, and thus vanishes. Every share distributed must be so for a reason, therefore it is necessary: how can there be a surplus left, unless we assume some sort of indeterminacy? This can be assumed from some subjective standpoint, where something is taken as known and given to him, but something is left unknown and dependent upon his will or his actions. But from a purely objective point of view, all must be {an} object of knowledge, and nothing can be indeterminate.

This is the great difficulty: the surplus is the object of the inquiry, but as soon as it is explained, a cause is found for it, and {it} ceases to be a surplus. This

sounds as if the object of the inquiry had been defined as 'the unknown', but if the inquiry is successful it becomes known, and the object of the inquiry ceases to exist!

Was there a way out of the impasse? Sraffa in fact saw two such ways. We turn immediately to the second alternative which Sraffa adopted:

Another solution however lies in *criticizing the above application of the principle of sufficient reason.*

Any given effect is entirely contained in its causes. (But these causes may contain something else besides that effect; i.e. they may have other effects as well).

Any given cause is entirely contained in its effects. (But these effects contain more than it, i.e. they have also other causes).

The two above statements cannot be rolled into one, except in the form 'all effects are contained in all causes': this is meaningless, and at any rate tautological, for 'all effects' would be merely another name for 'all causes' (if they meant anything at all).

Thus there must be a leak at one end or the other: the 'closed system' is in communication with the world.

When we have defined our 'economic field', there are still outside causes which operate in it; and its effects go beyond the boundary. This must happen in any concrete case. ...

The surplus may be the effect of the outside causes; and the effects of the distribution of the surplus may lie outside. (D3/12/7: 161 (3-5); emphases added)

The existence of a surplus is thus explicitly taken to reflect some 'outside causes' in operation. What are henceforth studied by Sraffa in terms of the equations of production are some of the effects of these causes, but not the causes themselves.

An echo of this argument can be found in a note of 1942 in which Sraffa defined his aim as follows:

This paper deals with an extremely elementary problem; so elementary indeed that its solution is generally taken for granted. The problem is that of *ascertaining the conditions of equilibrium of a system of prices and the rate of profits, independently of the study of the forces which may bring about such a state of equilibrium.* Since a solution of the second problem carries with it a solution of

the first, that is the course usually adopted in modern theory. The first problem however is susceptible of a more general treatment, independent of the particular forces assumed for the second; and in view of the unsatisfactory character of the latter, there is advantage in maintaining its independence. (D3/12/15: 2; emphasis added)²⁵

The persistence of Sraffa's new specification of the 'economic field' he wanted to investigate becomes apparent when we turn to the 1950s and see Sraffa begin drafting the preface of his book. In a draft dated 2 April 1957 he expounded:

This is not proposed as a complete system of equilibrium. The data assumed are not sufficient to determine either distribution or values. Only the effects of hypothetical, arbitrarily assumed extra data (such as the wage, or the rate of profits) are discussed. (D3/12/46: 32a)

This 'preliminary' Sraffa explicitly designed for the purpose of finding out 'whether there is room enough for the marginal system' (ibid.). Or, as he had emphasized in a note dated 16 September 1956: the book was meant to accomplish two tasks: (i) 'to facilitate the interpretation of some/certain theories of the classical economists and of Marx which seem puzzling/to puzzle the present-day/modern student'; (ii) 'to supply a platform (base, formulation) for a critique/re-examination of the marginal theory of production and distribution' (ibid.: 32b).

In the light of what has just been said it comes as no surprise that the idea of reducing interest (profits) or rents to some social cost or other disappears largely from Sraffa's papers after August 1931. Sraffa no longer advocated a 'natural science point of view' which amounted to finding sufficient cause for each and every effect or magnitude contemplated. However, he firmly adhered to the objective of rooting profits in the existence of a social surplus and of representing 'the production and circulation of commodities in material terms (i.e. quantities of labour, of commodities and periods of time) *independent of* the distribution of the product, i.e. of the rate of profit.' (D3/12/27: 11) The question was: Could this be accomplished? Sraffa knew that the answer was in the affirmative as regards systems with only circulating capital. Did it carry over to systems with fixed capital?

²⁵ In this context, see also Sraffa's annotations in Pareto (1902b and 1906) and his critical comment on the forces contemplated by the Lausanne economist in D3/12/9: 93.

6. Objectivism and the problem of fixed capital

Right from the beginning of his constructive work Sraffa was confronted with a problem that had the potential, or so it seemed, of thwarting his objectivist point of view: the problem of fixed capital. This problem had already bothered the classical economists who had seen that durable instruments of production introduce a complication into the theory of value and distribution. While the circulating part of the capital advanced at the beginning of the period of production contributes entirely to the annual output, that is, 'disappears' from the scene at the same time as its value is transferred to the product, the contribution of the durable part is less obvious and the idea of a material-cum-value transmigration into the product appears to lose any foundation. How then to deal with fixed capital in the theory of value and distribution?

Here is no need to describe in detail the path Sraffa followed until he finally managed to solve the problem in terms of the joint-products method since we have done so elsewhere (see Kurz, 2003, Kurz and Salvadori, 2004 and 2005). A brief summary account of the main steps he took in so far as they are pertinent to the theme of this paper must suffice.

In the winter of 1927-28 Sraffa sought to cope with the difficulties fixed capital posed in terms of reducing it to circulating capital on the one hand and land on the other: whereas the former enters in its entirety into the product, the latter does not enter into it at all. This necessitated assuming a 'social' point of view focusing attention not on single items of ageing fixed capital but on whole groups of such items characterised by a balanced age composition. The following numerical example explains the dichotomy he had in mind:

Suppose that we have 100 looms: that each loom lasts 10 years, and that 10 are 10 years old, 10 are 9 years old ..., 10 are new. Average age 5 years. Now, at the end of the year we shall have scrapped 10 looms 10 years old, and all the others will have grown 1 year older. ... The total decay is equal to 10 new looms. During the year we will have had to use so much circ. cap. as required to make 10 new machines. Therefore of the original 100 10 (one per age) were circulating cap., and 90 were fixed. (D3/12/4: 1(1-2))

In a related manuscript he made clear that the 90 aged machines actually constituted fixed capital of an everlasting character, that is, 'land':

The 90 old machines ... are there at the end of the year, in the exact state in which they were at the beginning, with exactly the same age composition and the same expectation of life – they have not grown any older, although a year has lapsed. As it were, they have been *mere spectators in production, they have*

"contributed" nothing, they have "transfused no part of themselves" into the produce. (D3/12/5: 13; emphasis added)

Sraffa added: 'The old machines are, to all effects, "land", viz. "undestructible"', but other than Ricardian land they are 'not original' (ibid.). He emphasized:

Depreciation, there is no such thing. Fixed capital is eternal: and working capital is entirely destroyed in one period of production. These two categories are exhaustive: *tertium non datur*. (D3/12/5:12-13)

This was certainly an ingenious device to deal with fixed capital,²⁶ but Sraffa quickly recognised that it had serious shortcomings. First, it did not allow one to ascertain the prices or book-values of ageing looms. Secondly, since an everlasting machine is not original, the 'scarcity' of such a machine cannot be treated on a par with the scarcity of Ricardian land. As a consequence, the theory of rent cannot be applied to it. Further, and most important: Was the approach really compatible with Sraffa's objectivist standpoint?

Sraffa in fact appears to have soon been clear about the fact that he could not leave matters at that. To begin with, he attempted to make good the first lacuna by complementing his approach with the 'Accountant's method'. Already in the winter of 1927-28 we see him employ the well-known annuity formula which he had adopted from books on commercial arithmetic.²⁷ While he saw that this method applied only to the special case of constant efficiency, with its help he was able to establish a number of important facts in capital theory (see Kurz and Salvadori, 2004). The main drawback of superimposing the accountant's method on his own analysis was of course that the former implied a partial perspective taking the prices of some commodities as given. Yet what was badly needed was a consistent *general* analysis capable of coping with the problem 'that a change in the rate of interest means a total revolution in the values of commodities, including machines' (D3/12/7: 139-40). The accountant's method was of no help in this regard.

From the summer of 1928 to the beginning of 1931 Sraffa basically continued to think of fixed capital as reducible to circulating capital and land. However, there are clear signs of growing doubts as to the sustainability of this view (see, in particular, D3/12/13: 16 (1-18)). Was there a

²⁶ As Sraffa noted, it can be traced back to Johann Heinrich von Thünen; see D3/12/10: 37.

²⁷ On 9 December 1927 we find in Sraffa's Cambridge Pocket Diary a reference to 'Commercial Arithmetic'; see E1.

compelling alternative to it? In a paper written in November 1931 he specified the main problem of fixed capital as consisting in the fact that it gives rise to a *sequence of outputs over time*, or intertemporal joint production. His concern with measuring the various kinds of machinery 'in *physical units*' is clearly expressed. In this context it is worth mentioning that Sraffa had come across more or less clear expressions of the joint-products method already in the writings of Marshall and Marx in the late 1920s, but at the time had considered it as misleading (see Kurz and Salvadori, 2004, section 4).

In September 1942 Sraffa reformulated the distinction between circulating and fixed capital in the following way:

We distinguish units of input into two classes:

- a) those which can be followed during their transit through production and traced on a given unit of output. These form Circ. Capital
- b) those which cannot be so traced, because they are used in the production of a succession of units of output and only gradually wear out. These Fixed Cap. (D3/12/21: 49)

Sraffa now no longer followed the idea that had guided him during the first period, he rather sought a solution of the vexed problem by reducing fixed capital entirely to circulating capital. The revised perspective, and the stage of maturity of his thoughts, are well expressed in a paper dated 'Oct. 1942' and titled 'Fixed Capital Equivalent Circulating' (D3/12/27: 46). He wrote:

The difficulty arises from this: for circulating capital, at the same moment that its value passes into the product, in most cases, also the material substance which is the bearer of that value, either passes into the product (raw material) or anyway passes out of the process of production (e.g. fuel). On the other hand, for fixed capital, the transfer of value from, e.g., the machine to the product, appears as a purely abstract process, which takes place without any corresponding transfer of material substance: that value is passed is undoubted, for the machine decreases in value while the product increases, but the machine remains complete in all its parts, with its efficiency unimpaired for the time being, and ready to resume operation in the next year.²⁸

In order to see how this abstract process takes place an abstract point of view is inevitable.

²⁸ In the margin of this passage Sraffa put a straight line.

We must first notice that when the rate of profit rises a piece of circ. cap. adds more to the price of the product, in the shape of additional profit upon itself. But that is not all: the circ. cap. itself changes in prices (rises or falls) and this is an additional source of change (+ or –) in the addition to the price of the product.

The same happens for fixed cap. While the annual capital charge *increases*²⁹ with r , the price of the new machine also changes, and thus the charge is changed. But the machine has one more degree of freedom than the circ. cap. While the latter must multiply every part of its value by $(1+r)$, as that is the only profit factor which it has, the machine has a whole range of choice {sic}. For it must multiply the part of its own price which it transfers to the product of the first year of its own life, by $(1+r)$; the part transferred to the product of the second year by $(1+r)^2$; etc.; and the part transferred to the product of its last year by $(1+r)^n$.

But this process of transfer is purely abstract ...; and while the machine is bound to transfer parts equal in magnitude of value each year, it is free to choose *which* particular part it will transfer in any one year. For these parts of value though equal in magnitude, need not be equal in kind: the machine has been produced by a certain quantity of commodities and by a certain quantity of labour, and accordingly it derives its value in part from the former and in part from the latter.

And on 17 October he added:

Why do we want to reduce Fixed Cap. to Circulating Capital?

Because we must prove that the only quantities whose knowledge is required to determine prices are the Capital Inputs; while the Capital Stock is not required, and anyhow is only a derived quantity, derived from the inputs. (D3/12/27: 46 (1-5); the last emphasis is ours.)

In mid November 1942 Sraffa asked his 'mathematical friend' A. S. Besicovitch to help him with reducing fixed capital to circulating capital, where the different circulating capital parts exhibit different 'rotation periods' (D3/12/27: 6, see also Kurz and Salvadori, 2004). Besicovitch solved the problem, but the 'purely abstract' character of the involved process of value transfer was hardly able to put Sraffa's mind at rest. In fact, on 4 December 1942 he jotted down a short piece titled 'Fixed into Circ. – *Objective basis*'. In it he wrote:

²⁹ In the manuscript the word has a wavy underlining which Sraffa in all probability added when re-reading the paper.

It may now be asked, can the matter be left at that? Certainly not. For it is against the object of the present treatment which is to represent the production and circulation of commodities in material terms (i.e. quantities of labour, of commodities and periods of time) *independent of* the distribution of the product, i.e. of the rate of profit.

This can be seen at once if we try to apply Reduction. How much labour, and of what period enters into a commodity. The answer would be, it *depends* on r . If we thus make the quantity of labour entering a commodity depend on r , we are falling straight into the Böhm-Bawerk-Wicksell blunder of making the period of production depend on the rate of interest. ... Which would reduce the whole scheme to nonsense.

He added:

Therefore it is necessary to make the transformation of Fix. into Circ. in terms, *not* of proportionate parts varying with r , but of actual quantities of labour and commodities, of such magnitudes and of such periods that they will *happen* to vary in price (and not in quantity) as those proportionate parts. (D3/12/27: 11-12)

Four days later he reiterated that by 'objective' he meant '*giving for each instalment quantities of labour and commodity which are independent of r* ' (D3/12/27: 8 (1); emphasis added).³⁰

After another comparison of his latest treatment of fixed capital with the accountant's method and some further deliberations on the joint-products approach Sraffa, on 10 December 1942, adopted the latter for good (see D3/12/30: 5-8 and 10).³¹

³⁰ It goes without saying that this requirement does not refer to the case in which a change in the rate of profits involves a change in the technique employed by cost-minimizing producers and thus a change in the quantities of labour and means of production needed in the new situation. This proviso applies also with regard to the passage used as a motto of this paper.

³¹ In the remaining days of December 1942 he investigated the solvability of the equations related to the introduction of an equation for each age of the machine and whether in the case of constant efficiency the accountant's method gives the same result as the joint-products method. See Kurz and Salvadori (2004).

At long last Sraffa had managed to overcome an 'insuperable obstacle', using Wicksell's term (see D3/12/27: 47), on the way towards an objectivist approach to the theory of value and distribution. His concern with a representation of the production and circulation of commodities in strictly material terms had pushed him to eventually adopt the joint-products method of dealing with fixed capital because all other methods had turned out to be incompatible with this overriding concern – the star guiding his analysis, so to speak – or at any rate exhibited serious deficiencies of various sorts. However, the problem of fixed capital was not the only obstacle Sraffa had to overcome; another one is mentioned in the concluding section.

7. Conclusion

In this paper we dealt with Sraffa's elaboration of an objectivist alternative to the subjectivist-cum-marginalist approach to the theory of value and distribution and some of the difficulties he encountered and how he solved them. Sraffa considered his own analysis as rooted in the writings of the classical authors, especially William Petty and the Physiocrats, and as being faithful to the spirit of their explanation of economic phenomena of modern society strictly 'in Terms of Number, Weight or Measure', to use Petty's famous specification of the method that was considered congenial to the new subject of political economy. At first Sraffa was of the opinion that the classical authors' reference to labour instead of 'food' involved a 'corruption' of the approach resulting in no small measure from their inability to bring to fruition two major concepts of their analysis in a coherent framework: that of *physical real cost-cum-social surplus* and that of production envisaged as a *circular flow*. Not having the tool of simultaneous equations and not knowing how to solve them they could not avoid having recourse to roundabout ways in order to determine the rate of profits and relative prices. Initially Sraffa even disputed that labour was a quantity at all that could be used in the theory of value. However, his transition from the concept of inventory (i.e. subsistence) wages to Ricardo's concept of proportional wages, which was designed to cover the case in which workers participated in the sharing out of the surplus product, forced him to reconsider his previous view. Toward the end of the first period of his constructive work Sraffa in 1931 developed a second way of approach to the theory of value and distribution in addition to the one in terms of simultaneous equations: the reduction to dated quantities of labour. The two approaches together then allowed him to see when the labour theory of value applied, and when not. Hence, the labour theory of value was not the starting point of his analysis, as has occasionally been contended.

It is argued that Sraffa's concept of objectivism changed over time. In the first period of his constructive work he advocated a concept that was informed by the natural sciences, especially physics. He was then seeking to elaborate an 'atomic analysis'. The central premise of this science point of view was 'that for every effect there must be sufficient cause, that the causes are identical with their effects, and that there can be nothing in the effect which was not in the causes: in our case, there can be no product for which there has not been an equivalent cost, and all costs (= expenses) must be necessary to produce it.' We therefore find Sraffa searching for sufficient cause of all property income, profits and rents, and reducing them to 'socially necessary' as opposed to 'natural' costs. However, by the time of August 1931 Sraffa saw that this supposedly 'entirely objective view' did not allow him to avoid discussing 'inducements' and thus subjective elements. Sraffa therefore decided to abandon this concept of objectivism and henceforth define the 'economic field' in such a way that 'there are still outside causes which operate in it; and its effects go beyond the boundary ... The surplus may be the effect of the outside causes; and the effects of the distribution of the surplus may lie outside.' Hence he no longer sought to reduce profits and rents to some cost or other but rather to determine their levels, together with the relative prices supporting a given distribution of income, exclusively in terms of 'quantities of labour and commodity which are independent of {income distribution}.'

With this amended perspective, Sraffa in the second (and third) period of his constructive work then had a fresh go at problems he had been unable to solve previously. These concerned in particular the problem of fixed capital with regard to which the idea of a material-cum-value transmigration from input to output as in the case of circulating capital appeared to lose any foundation. After several unsatisfactory attempts at durable instruments of production Sraffa eventually, in December 1942, adopted the joint-products method which was faithful to his overriding concern of representing production and circulation in strictly material terms within the framework of a general analysis.

The problem of fixed capital was not the only one which seemed to cause difficulties for his objectivist approach to the theory of value and distribution. Another and somewhat different problem was posed by the case of intensive rent. Initially Sraffa thought that the problem could not be dealt with because it necessitated, or so it appeared, to take into consideration 'changes in the scale of production or in the proportions of "factors"' (Sraffa, 1960, p. v).³² Such changes were a characteristic feature of marginalism and had no role to play in the approach he was

³² The problem of extensive rent he had substantially solved as early as 1928; see, in particular, D3/12/7: 131-132.

about to elaborate. It was only in the 1950s that he convinced himself that this opinion could not be sustained and how the case could be tackled: in terms of the use of two methods of production employed side by side on land of a given quality. These two methods were observable and thus an objective fact. In the first period of his constructive work he had not yet worked out this idea. He rather followed the conventional marginalist approach to the problem of intensive rent which dealt with it in terms of the employment of incremental "doses" of capital. However, as Sraffa objected, these "doses" could not be defined independently of prices:

The fundamental difference is that the *extensive* (different qualities of land) is truly a purely *timeless*, or geometrical representation: all the different lands exist simultaneously, at one instant, they and their products can be ascertained, distinguished and measured at one instant, without changing anything in the present arrangements.

On the contrary, the *intensive* (successive doses of c. and l. on a piece of land) dim. ret. do not exist at any one instant: the "doses" are (supposed to be) all identical, and since there is not a location in space of each of them (each is applied on all the surface of land) we have no knowledge of (and there is no meaning in the expression) the product of a separate dose: we know only the product of all together, and if we like we may deduce an average. We can only find these dim. ret. by *change*, or movement: that is to say, we require *time*. (D3/12/13: 23 (1, 1bis and 2))

At long last, however, Sraffa was able to solve also this riddle and determine prices and rent "on land of a single quality" (Sraffa, 1960, p. xi). But this is too long a story to be told in so short a paper.

References

(Books in Sraffa's library are referred to at the end of the usual information in brackets, providing the number of the book under consideration as it is catalogued in Trinity College Library, Cambridge.)

Allen, H. S. (1928), 'The quantum theory', *Nature*, Supplement, No. 3084, December 8, pp. 887-95.

- Anonymous (1821), *An inquiry into those principles respecting the nature of demand and the necessity of consumption, lately advocated by Mr Malthus, from which it is concluded, that taxation and the maintenance of unproductive consumers can be conducive to the Progress of Wealth*. London: R. Hunter. (Sraffa 1488). Reprinted in a reprint of S. Bailey, *A Critical Dissertation on the Nature, Measure and Causes of Value*, first published in 1825, London: R. Hunter, New York, 1967: Augustus M. Kelley.
- Bridgman, P. W. (1927), *The Logic of Modern Physics*, New York: Macmillan. (Sraffa 3617)
- Cunningham, W. (1892), 'A plea for pure theory', *Economic Review*, **11**, pp. 25-41.
- Eddington, A. S. (1928), *The Nature of the Physical World*, Gifford Lectures 1927, Cambridge: CUP. (Sraffa 3080)
- Garegnani, P. (2004), 'Di una svolta nella posizione teorica nella interpretazione dei classici in Sraffa nei tardi anni 20', in *Atti dei Convegni Lincei 200*, Accademia Nazionale dei Lincei: Roma, pp. 159-94.
- Gehrke, C. (2003), 'Price of Wages: A Curious Phrase', manuscript, Graz.
- Gehrke, C. and Kurz, H. D. (2003), 'Sraffa on von Bortkiewicz. Reconstructing the Classical Theory of Value and Distribution', forthcoming in HOPE.
- Gentile, G. (1899), *La filosofia di Marx: studi critici*, Pisa: Enrico Spoerri. (Sraffa 3363)
- Hertz, H. (1899), *Principles of Mechanics*, London:
- Keynes, J. M. (1971 et seq.), *The Collected Writings of John Maynard Keynes*, Vol. X (1972), London and Basingstoke: Macmillan. In the text abbreviated as CW X.
- Kurz, H. D. (2003), *Sraffa's Early Studies of the Problem of Fixed Capital: Towards an Atomic Analysis*, manuscript, revised version, Graz.
- Kurz, H. D. and Salvadori, N. (2004), "'Man from the Moon". On Sraffa's Objectivism', paper given at a conference of the Charles Gide Society in Strasbourg in 2001. To be published.
- Kurz, H. D. and Salvadori, N. (2004), 'On the Collaboration between Sraffa and Besicovitch: The Cases of Fixed Capital and Non-Basics in Joint Production', in *Atti dei Convegni Lincei 200*, Accademia Nazionale dei Lincei: Roma, pp. 255-301.

- Kurz, H. D. and Salvadori, N. (2005), 'Removing an "Insuperable Obstacle" in the Way of an Objectivist Analysis: Sraffa's Attempts at Fixed Capital', forthcoming in *The European Journal of the History of Economic Thought*, **12**.
- Labriola, A. (1922), *Il valore della scienza economica: introduzioni a una critica dell'economia politica*, Napoli: Alberto Morano. (Sraffa 3577)
- Marshall, A. (1970), *Principles of Economics*, 8th edn 1920, reprint, London: Macmillan.
- Marx, K. (1924-25), *Oeuvres complètes de Karl Marx. Histoire des doctrines économiques*, translated by J. Molitor, 8 vols, Paris: Alfred Costes. (Sraffa 3699)
- Marx, K. (1972), *Theories of Surplus Value*, Part 3, London: Lawrence & Wishart.
- Mill, J. (1826), *Elements of Political Economy*, 3rd edn, London: Baldwin, Cradock, and Joy. (Sraffa 1363)
- Pareto, V. (1901), 'Le nuove teorie economiche', *Giornale degli economisti e annali di economia*, **23**, pp. 235-59.
- Pareto, V. (1902a), *Les systèmes socialistes*, two vols, Paris: V. Giard & E. Brière. (Sraffa 1774)
- Pareto, V. (1902b), 'Anwendungen der Mathematik auf Nationalökonomie', in *Encyklopädie der mathematischen Wissenschaften*, vol. I, No. 7, pp. 1094-1120, Leipzig: B. G. Teubner. (Sraffa 4536)
- Pareto, V. (1906), *Manuale di economia politica con una introduzione alla scienza sociale*, Milan: Società editrice libraria. (Sraffa 699)
- Petty, W. (1691), *Political Arithmetick, or A Discourse Concerning ...*, London: Printed for Robert Clavel at the Peacock and Hen. Morlock at the Phoenix in St Paul's Church-yard. (Sraffa 305, 363) Reprinted in W. Petty, *The Economic Writings of Sir William Petty*, edited by C. H. Hull, vols I and II, originally published in 1899, Cambridge: Cambridge University Press. (Sraffa 1587) Reprinted in one volume (1986), New York: Kelley.
- Poincaré, J. H. (1902), *La Science e l'Hypothèse*, Paris: Ernest Flammarion. (Sraffa 3137)
- Predella, P. (1915). *Algebra ed Aritmetica: ad uso dei licei*, Turin: G. B. Paravia. (Sraffa 3203)

- Ricardo, D. (1891), *Principles of Political Economy and Taxation*, ed. by E.C.K. Gonner, London: G. Bell and Sons. (Sraffa 1699)
- Ricardo, D. (1951-73). *The Works and Correspondence of David Ricardo*, 11 volumes, edited by P. Sraffa with the collaboration of M.H. Dobb, Cambridge: Cambridge University Press. In the text referred to as *Works*, volume number and page number.
- Schrödinger, E. (1944), *What is Life? The Physical Aspect of the Living Cell*, Cambridge: Cambridge University Press. (Sraffa 3103)
- Smith, A. (1976). *An Inquiry into the Nature and Causes of the Wealth of Nations*, 1st edn 1776, Vol. II of *The Glasgow Edition of the Works and Correspondence of Adam Smith*, edited by R. H. Campbell, A. S. Skinner and W. B. Todd, Oxford: Oxford University Press. In the text quoted as *WN*, book number, chapter number, section number, paragraph number.
- Sraffa, P. (1960), *Production of Commodities by Means of Commodities*, Cambridge: Cambridge University Press.
- Whitehead, A. N. (1926), *Science and the Modern World*, Lowell Lectures 1925, Cambridge: Cambridge University Press. (Sraffa 662)
- Whyte, L. L. (1928), *Archimedes or The Future of Physics*, London: Kegan, Paul, Trench, Trubner & Co., New York: E. P. Dutton & Co.