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First steps for a Sraffian ecological economics. An answer to Martins' "The Classical Circular Economy, Sraffian Ecological Economics and the Capabilities Approach"

Yoann Verger

February 12, 2018

Abstract

Here I provide some further elaboration on the idea of Sraffian ecological economics and its articulation with the capability approach. This enables addressing some important questions raised by Nuno Ornelas Martins (2018) when commenting on the idea of Sraffian ecological economics as outlined in Verger (2017b) while advancing the basis for a capability approach. In a more general way, a research pathway for the development of Sraffian ecological economics is presented, going from an historical work on the epistemological, ethical, and ontological positions of Sraffa, to the investigation of specific areas of research. Finally, to understand the connection between Sraffa's economic theory and the capability approach discussed by Martins (2018), while addressing the environmental impacts of production, an essential aspect is Pasinetti's concept of hyper-subsystem (Pasinetti, 1988), as suggested by Vivian Walsh (2003).

1 Introduction

The idea of Sraffian ecological economics advanced in Verger (2017b) combines Piero Sraffa's (1960) interpretation of classical political economy with ecological economics goals and principles. In a recent critique of this conception, Martins (2018), although noticing that the idea of Sraffian ecological economics is essentially based on the criticism of neoclassical position and neoclassical imperialism, focuses on the concept of classical subsistence wage and Standard commodity to show that a constructive stance can be build on Sraffa's theory.

The final outcome of Martins' (2018) comments is not so much a discussion of the idea of Sraffian ecological economics, but rather a more specific thing, that is, the advancement of the connection between the idea of classical circular approach and the capability approach as originally proposed by Amartya Sen (1980) and Martha Nussbaum (2000), following a line of research subsequently

advanced by Vivian Walsh (2000; 2003), and that he has begun to develop in Martins (2011; 2013; 2016).

Here I shall elaborate further on the idea of Sraffian ecological economics and its articulation with the capability approach, while providing a reply to Martins' (2018) critique of the use of Sraffa's theory when advancing the idea of Sraffian ecological economics in Verger (2017b). To do so, I firstly discuss two ideas that Martins (2016; 2018) presents as constructive: Sraffa's interpretation of the classical meaning of wages, and the Standard commodity "as a common unit in terms of which biophysical processes can be compared in theory, while at the same time using it as a possible way to achieve efficiency in the production of commodities" (Martins, 2018).

While I agree that the classical idea of a subsistence wage can be used in a constructive way, and especially in connection with the capability theory, I deny the fact that the Standard commodity could be used in the way Martins has suggested. The Standard commodity is an analytical tool that is part Sraffa's theory of value, itself inspired by the classical theory of value of Ricardo and Marx. The goal of this theory of value is mainly critical: it is to show that the neoclassical distribution theory is not coherent, especially when it asserts that factor revenue should be linked with marginal productivity.

The discussion on these ideas also facilitates the clarification of the role that Sraffian ecological economics can play within ecological economics. So besides replying to Martins (2018), this is a good opportunity to provide some further elucidations on what can be a research program that would seek to use Sraffa's theory to develop ecological economics. Therefore, after explaining that Sraffa's ideology and epistemology should be clarified before adapting them to ecological economics, I explain within which areas of economic and environmental analysis and management Sraffian ecological economics should be developed. Finally, I present the case of hyper-subsystem, a concept first introduced by Pasinetti (1988; 1989), as an analytical tool that can be used to integrate the capability approach into Sraffian ecological economics, while addressing the environmental impacts of production.

2 On Martins (2018)

2.1 On what I agree

I shall refer, in this subsection, only at the points of agreement with Martins (2018), leaving the points of disagreement to the next subsection. My points of agreement mainly are on two notions: the importance of the classical notion of subsistence in Sraffa, and Martins' personal view on the development of the capability approach.

First, Martins rightly highlights the fact that Sraffa conceives the more appropriate notion of wage as a wage composed by two separate parts, the subsistence wage: "as consisting of specified necessities determined by physiological or social conditions which are independent of prices or the rate of profits" (Sraffa,

1960, §44); and the surplus wage: “besides the ever-present element of subsistence, [wages] may include a share of the surplus product” (Sraffa, 1960, §8). Furthermore, Sraffa asserts that, if the whole wage must be treated as a variable, as he does in his analysis, we could introduce “a limit below which the wage cannot fall; a limit which would itself fall with any improvement in the method of production of necessaries, carrying with it a rise in the rate of profits and a change in the prices of other products” (Sraffa, 1960, §8).

Thus I agree with Martins that “Sraffa’s revival of classical political economy presupposes an objective analysis of the physiological and social conditions that determine a certain standard of living” (Martins, 2018). This objective analysis can help to define, for each system of production, what should be the subsistence wage, leaving aside the question of what should be the level of the surplus wage. And to define the subsistence wage, Martins advances that the capability approach is a promising pathway.

In this perspective, the subsistence wage should be the one that allows the purchase of a set of goods and services that are considered necessary to guarantee access to all the basic capabilities. The list of the basic capabilities that each one should have access to should be decided through a democratic process of decision informed both by universal principles about the basic capabilities that should be accessible to all humans, and by local cultural and technical features, as well as local preferences.

Martins indicates that the construction of universal principles should be informed by an “ontology of Aristotelian potentials or causal powers enabled by underlying physiological and social structure” (Martins, 2018). I agree with him that this appears to be a promising strategy, as well as I agree with his defense of Nussbaum (2003) when she asserts, against Sen, that it is possible to construct a universal list of basic capabilities that would be independent from local preferences (whereas Sen focuses more on the importance of liberty, suggesting that each community of agents should be left free to decide its own list of basic capabilities - see for instance Sen, 2013).

2.2 On what I do not agree

My main points of disagreement with Martins (2018) refer to his use of the Standard commodity and to his apparent interpretation of Sraffa’s epistemic values.

2.2.1 Standard commodity and waste

The Standard commodity is a mixed commodity whose commodities are in the same proportion as the commodities in the surplus of the Standard system (Sraffa, 1960, Chapter IV). The Standard system is an imaginary construction: from the real system, the processes are reduced or increased in size, with constant returns to scale, so that the commodities used as inputs are in the same proportions as the commodities used as outputs (we can call these proportions the Standard proportions).

Martins asserts that the Standard commodity and the Standard system could be used as analytical tools to investigate the environmental efficiency of the system, and more precisely to diminish waste production:

“the Standard commodity is suggested in Martins (2016) as a common unit in terms of which biophysical processes can be compared in theory, while at the same time using it as a possible way to achieve efficiency in the production of commodities. This is so because in Sraffa’s Standard system, the proportions in which commodities are used as inputs are the same proportions in which they are used as outputs. If inputs are being produced exactly in the same quantities and proportions as they are used, it is possible to achieve a situation in which no waste is generated in the system, if the total quantity of commodities produced is equal to the total quantity of commodities used, since inputs are being exactly replaced by the outputs produced. This contributes to sustainability, even if it is not a sufficient condition for it to exist.

...
The point emphasised in Martins (2016) when resorting to the idea of a Standard system and the Standard commodity is the need of achieving no waste in the production of reproducible commodities, that is, reproducing whatever inputs are used in the same proportions and quantities as they are used, which leads to no waste when the total quantities of outputs and inputs are equal.

...
In short, the Standard system is used to address the problem of waste, reducing the latter through the use of balanced proportions” (Martins, 2018).

Hence, Martins seems to say that if a system only produces what it is using (simple reproduction without surplus), the system will be in the Standard proportions and no waste will be produced. What I want to answer is that, while it is true that a system in a self-replacing state is a Standard system, this does not imply that no waste are produced, unless the system under consideration is the Earth.

First, a commodity is not a waste: when Martins says that the quantities of outputs will be exactly the same as the quantities of inputs, so that there is no surplus and no waste, he is talking (as Sraffa does) about commodities. But during each process of production and consumption, wastes are produced (heat, gaseous emissions, tiny part of materials, scraped fixed material, etc.) and they are not represented in the system of production of commodities. A clarification of the distinction between commodities and waste is needed.¹ A commodity is

¹This refers to the distinction I made in Verger (2017b) between the system of physical exchanges of matter and energy and the system of value equations, where in the latter only commodities are represented. Flows of matter and energy can be used to characterize the system of production of commodities in a physical way, but the commodities are defined at the social level, not at the physical level.

something that is sold to someone and, hence, receives a price. More precisely, a commodity is defined by Sraffa as something produced by an industry and exchanged on a market for other commodities. A waste is something produced by an industry, but not exchanged on the market. Hence, a waste does not usually receive a price. Only if it is recycled, it can have a price, and can thus be represented in Sraffa's system:

“if the scrap (metal, timber, etc.) is interchangeable in use with some other material already accounted for, it simply assumes the price of the latter without need of an additional process; if it is not completely interchangeable (e.g. scrap iron as compared with pig iron), then there will be room for two processes, producing the same commodity (e.g. steel), but differing in the proportions in which they use the two types of material” (Sraffa, 1960, § 74).

Otherwise, a waste does not receive a price and does not appear in Sraffa's system.²

Second, I understand that Martins wants to achieve a situation where all processes of production manage their wastes in such a way that no waste is released in the environment. But all processes of production and consumption, even if they are optimized to recycle the most of the waste produced, will generate some waste that will be lost in the environment. Hence, the only possibility to have no material waste in a system of production is to consider the whole Earth as the system of production. In this case, we would indeed obtain a system in standard proportions, as the Earth system is in a steady-state position from the material point of view (this could even be disputed, as some matter are transformed into energy in nuclear reactions, Georgescu-Roegen, 1979). But in this case, although the theory is exact, the application of the theory would be meaningless, as it would mean that we are already in a sustainable system with no waste.

2.2.2 Epistemic values

This brings me to the second point of disagreement with Martins, his interpretation of Sraffa's epistemic values. On this subject, Martins says that “Sraffa is measuring value at a theoretical level, in order to achieve an exact theory, and not at an empirical level. ... no economic model provides a complete description of the conditions for sustainability, not least because it is not possible to measure with mathematical exactness all the biophysical processes taking place at an empirical level.” Hence, it seems to me that Martins suggests that to consider the whole Earth as a system of production would be valid from a theoretical point of view, even though it is not possible to apply the theory at the empirical level. The suggestion implies that a theory could be accepted as long as it is exact, although it cannot be applied at the empirical level. As a reply,

²It should be added that the price of the service of waste removal should not be confused with the price of the waste (the removal of a waste can be costly, and thus the service of the waste removal can receive a price, if an industry sells this kind of service - see Verger, 2016).

I advance that this suggestion would be a bad interpretation of the epistemic values defended by Sraffa.³

Sraffa has never explicitly written on the matter of epistemic values. He has nevertheless expressed some thoughts on the difference between the theoretical level and the empirical level, and on the usefulness of theory, during a conversation with John Hicks at a conference in Corfu (1958, cf. Hague and Lutz, 1961 for the proceedings):

“Mr. Sraffa thought one should emphasize the distinction between two types of measurement. First, there was the one in which the statisticians were mainly interested. Second there was measurement in theory. The statisticians’ measures were only approximate and provided a suitable field for work in solving index number problems. The theoretical measures required absolute precision. Any imperfections in these theoretical measures were not merely upsetting, but knocked down the whole theoretical basis. One could measure capital in pounds or dollars and introduce this into a production function. The definition in this case must be absolutely water-tight, for with a given quantity of capital one had a certain rate of interest so that the quantity of capital was an essential part of the mechanism. One therefore had to keep the definition of capital separate from the needs of statistical measurement, which were quite different. The work of J. B. Clark, Bohm-Bawerk and others was intended to produce pure definitions of capital, as required by their theories, not as a guide to actual measurement. If we found contradictions, then these pointed to defects in the theory, and an inability to define measures of capital accurately. It was on this - the chief failing of capital theory - that we should concentrate, rather than on problems of measurement.

Professor Hicks was not quite clear about this. Did Mr. Sraffa mean to equate models with theories? He could see that in a particular model one could only make that model water-tight by introducing drastic simplifications. Only thus, for example, could one have a clear and precise definition of capital stock. But some simplifications were so drastic that he himself was simply not interested in any theory based on them.

Mr. Sraffa replied that Wicksell’s might be a simple model in that he worked out a simple and general theory for future development. Surely the usefulness of any theory lay in its explanatory value. Was one only interested in a theory if one could fit actual figures into it; or was one interested independently of that?

Professor Hicks argued that if a theory was to explain the working of the social mechanism, it ought to be capable of having measurable

³I may add that it is possible that this suggestion was not intended by Martins: however, reading his article, I think this interpretation can naturally arise, so it seems to me important to clarify this point.

concepts fitted into it.

Mr. Sraffa took the view that if one could not get the measures required by the theorists' definitions, this was a criticism of theory, which the theorists could not escape by saying that they hoped their theory would not often fail. If a theory failed to explain a situation, it was unsatisfactory." (Hague and Lutz, 1961, pp. 305 - 306).

It could be that the discussion between Hicks and Sraffa was not recorded exactly, but what I understand from the record is that Sraffa defends two epistemic values for a theory: precision and explanatory value. If the theory cannot precisely define a concept, for instance in that case "capital" (how to measure capital, on which unit), it means that the theory is wrong. If the statistician cannot precisely measure it, but only roughly, this should not be a reason to discard the theory. However, if the statistician cannot measure the concept at all, i.e. if he cannot apply the theory, then it is because the theoretician is wrong, even though his theory is coherent and precise. The theory in this case is not useful. So there is two cases where we can say that we have a good theory: if it is precise (or exact), and if it is useful. Both are necessary to have a good theory.

Going back to my discussion on Martins (2018), I argue that if someone, in order to have a theory of economic-environment interactions that is exact, says that we should implement in it all the existing natural and economic processes, then the theory will be exact but not useful, as no-one will be able to use it for empirical purposes. It is true that it is not easy to apply Sraffa's theory at the empirical level, because the number of commodities and the number of processes required to produce these commodities are important. But at least each commodity sold is usually recorded in an accounting book, and most of the countries have reliable national accounting of commodities produced and sold. This is not the case for all wastes produced in the industrial system (although some physical accounts are starting to be implemented, taking explicitly into account waste - see Fischer-Kowalski and Haberl, 2015 for an overview) and more importantly, this is not the case for all the natural processes, in the whole world.

I must finally say that these points of disagreement are minor, and do not overcome the fact that Sraffian ecological economics should be articulated with the capability approach as developed by Martins (2011; 2013; 2016; 2018). But first Sraffian ecological economics must be more precisely defined, so I turn now to the work that must be done in this direction.

3 Sraffian ecological economics

In this section I will describe the relevant research pathway that will help to construct a coherent and useful description of what should be Sraffian ecological economics. The research on this development should be conducted along three lines. Following what Spash (2012) tried to do for ecological economics, it is important, first, to do an historical work on the epistemological, ethical, and

ontological positions of Sraffa that underline and shed light on his theory of value and, second, to engage in the development of an epistemological, ethical, and ontological position that would be the basis for Sraffian ecological economics. By doing this, the understanding of the relevant areas of environmental and economic analysis on which the development of Sraffian ecological economics can shed a new light will be improved. Once this is done, it will be possible to develop a coherent corpus of environmental policy tools for Sraffian ecological economics, and I will give an example of one of these tools in the next section.

3.1 Epistemology, ethics and ontology of Sraffa and Sraffian ecological economics

The first line of the work should be directed at understanding the meaning of Sraffa's equation from an epistemological, ethical, and ontological point of view. What was Sraffa aiming at? Was he only looking at correcting logical mistakes in the development of economic theory, or was his theory grounded on a completely different standpoint than the one of the neoclassical theory? The goal is to have a better understanding of his theory, especially on the question of the connection between theory and empirical facts (e.g. the empirical relevance of the uniform rate of profits in the equations, the meaning of the "photograph" metaphor – Verger (2017a) – or the importance of natural resources and their possible depletion in his model).

First results can be estimated from the published and unpublished writings of Sraffa and its conferences talks.⁴ We have just seen that about epistemic values, he is considering exactness and explanatory value as important. Martins (2016) also highlights Sraffa's objectivist approach. On ethics, Sraffa observes that Marx's defense of the right of the worker to get the whole national product is based on ethical positions. He criticizes the following circular reasoning, which was used to dismiss Marx's labor theory of value: "Distribution determines values, & values justify that distribution" (Sraffa's unpublished papers, August 1946 - 1948, D3/12/44: 7). For Sraffa, it is ethics and politics that determine the distribution of the national product, and this distribution that consequently determines the values.

Now, if it is accepted that Sraffa wanted to revive Marx (a thesis which is highly debated both in Sraffian and Marxist literature - see for instance Kurz, 2012; De Vivo, 2016; Sinha, 2016), we could assume that he was in favor of the ethics of Marx, and also of Marx's ontological presuppositions, which, according to Nussbaum (2000), are Aristotelian. If this is true, then we can fairly assume that Sraffa would have accepted the ontological assumptions that form the basis of the capability theory. And as highlighted by Martins (2016; 2018), Sraffa's

⁴Sraffa's unpublished papers, including his lectures, are kept at the Wren Library, Trinity College, University of Cambridge (UK) and they are for the most part available online. The online effort is directed by Giancarlo de Vivo and Murray Milgate with the collaboration of the Wren archivist Jonathan Smith. It is expected to be completed in 2017 and can be found at the following url: <https://janus.lib.cam.ac.uk/db/node.xsp?id=EAD%2FGBR%2F0016%2FSRAFFA>

objectivist approach is also a fact that supports the articulation between Sraffian ecological economics and the capability approach.

The second line of research aims at constructing an epistemological, ethical, and ontological proposal that could be the basis for the development of Sraffian ecological economics. The hypothesis underlining this line of research is that heterodox economics should base their criticism of the dominant theory, not only referring to logical and rational arguments, but also referring to concurrent ethical and political projects. This means that a concurrent ideology should be constructed in order to revive heterodox economics (Combemale, 2007). In this respect, the goal will be to analyze and try to reconcile in a relevant way the results of the first line of research with the current attempts to reconstruct a coherent set of epistemological, ethical, and ontological positions for the ecological economics field (Martins, 2011; Spash, 2012). I believe a first direction in this line of research would be to investigate the political neo-realist approach developed by Amable and Palombarini (2009), which is underpinned by the philosophical and political analyses of Gramsci (1975, 1977) and Castoriadis (1975). Unfortunately I do not have the possibility to develop further in this article this point of view, and I must now turn to the tools that could be integrated and developed within Sraffian ecological economics.

3.2 Relevant areas of analysis

The third line of research needs to show the relevant research areas for a Sraffian ecological economics. Ideas will emerge from the two first lines of the research, but three directions could already be pointed at.

First a reflection on the property regimes that should be attached to natural resources and wastes should be attempted, in relation to the question of their valuation and the rents that can be earned through their possession. The first attempts to use Sraffa in order to solve environmental questions usually concluded that natural resources and wastes should be included in the market of commodities to be managed in an efficient way (see Verger, 2016, 2017b). My hypothesis is that a solution for their sustainable management which would be more in accordance with Sraffa's ethical, ontological and political standpoint should avoid giving an exchange value to nature. For instance, the natural resource may be managed under the regime of common property, with rules of sustainable use that do not imply exchange of money between the users.

A second direction is pointed at by some authors in ecological economics (Ballet et al., 2011, 2013; Martins, 2013) and concerns the capability theory. My hypothesis is that the capability approach would fit well in Sraffian ecological economics, although an important work has to be made to make the approach operational, especially if we want to include environmental issues. The main question is: how can we control the economy so that it would produce the required set of basic capabilities, while not endanger the environment? Hence, this direction of research should be concerned with the construction of tools and indicators that will help to solve this question.

The third direction concerns ecological macroeconomics. Macro-ecological

economics is a little field, with few models, and only one which explicitly refers to Sraffa (Kemp-Benedict, 2014)⁵: all of them use either neoclassical or post-Keynesian models when they represent the production of goods and the distribution of surplus. It is to be noticed that the most promising path for developing ecological macroeconomics is described by Hardt and O’Neill (2017) in this way:

“Although current models are still at an early stage of development, the combination of environmentally-extended input-output analysis and stock-flow consistent modelling stands out as a promising avenue for integrating concerns about ecological impacts and financial stability”.

They also point to the most important questions to be answered by such models:

“One very important question, as highlighted in the introduction to this study, is how to achieve financial stability while decreasing consumption. Another important question is how a shift to lower-productivity sectors would affect incomes and inequality, or how the necessary investment for a post-growth transition can be realised without restarting the engine of economic growth itself” (Hardt and O’Neill, 2017).

I believe that Sraffa’s theory can be used to solve these questions. The interest of Sraffa’s theory is that it is a theory of value based on input-output analysis that allows the construction of rigorous macro-economic accounting tools. But two problems need to be handled first. To begin with, Sraffa’s analysis is static, so there is no possible discussion on the coordination of agents’ decision and possible equilibrium. To render its static analysis into a dynamic one, one could start with the work of Pasinetti (1988; 1989; 1993). An example of a development following Pasinetti’s approach is given in the following section. Second, money is not considered in Sraffa’s system. As Sraffa is only looking at one point of time, there is no need for money, or rather money would be only neutral in his system (it is obtained by selling commodities, and it is only used to buy commodities; there is no buying or savings of money taken into consideration). Of course, if dynamics are introduced, money and a financial system should be introduced next.

Once the research questions are defined, appropriate tools for theoretical and empirical analysis can be designed. In the next section, a tool is presented that

⁵Kemp-Benedict (2014) tries to express absolute rents on natural resources and to develop physical indicators of the efficiency of a system of production, by using a vertical integration analysis (Pasinetti, 1973). He attempts to express the part of GDP which is based on the use of environmental resource, as he tries to reveal Daly’s “inverted pyramid” (natural resources extraction accounts for only 5% of the global GDP but actually all production is directly or indirectly related to this initial extraction, Daly, 1995). However, my point of view is that he is not revealing the part of GDP related to the extraction of natural resources, because extracting natural resources is a necessary condition, in his system, to produce economic values. If there would not be any extraction, then GDP would be equal to zero. What he is actually revealing in his analysis is by how much the value of GDP increases when rents on natural resources are added.

can be used to link ecological macroeconomics with the capability approach: the concept of hyper-subsystem.

4 An example of a Sraffian ecological economics tool of analysis

Here I will now present an example of how Sraffian ecological economics could be developed, by introducing Pasinetti's concept of hyper-subsystem and linking this concept with the management of waste, the management of natural resources, and the capability approach (the latter connection - between Pasinetti's and the capability approach - has been suggested by Walsh, 2003).

Pasinetti's concept of hyper-subsystem (Pasinetti, 1988, 1989; Pasinetti and Garbellini, 2015; Garbellini and Wirkierman, 2014) is a theoretical refinement of Pasinetti's previous concept of vertically integrated sector (Pasinetti, 1973). This older approach was inspired by the notion of "sub-system" presented by Sraffa (Sraffa, 1960, Appendix A). Pasinetti showed that a system of production could be decomposed into vertically integrated sectors. Each sector produces only one commodity - either a capital good or a final consumption good - and is composed of the requirements in terms of labor and commodities for the production of this commodity at a given period (direct requirements), and for its reproduction during the next period (indirect requirements).

The new "hyper-subsystem" approach is used to investigate the direct, indirect, and what Pasinetti calls hyper-indirect requirements, for the production of one consumption good at a given period (direct requirements), for its reproduction during the next period (indirect requirements), and for the change in the rate of consumption of this good at the next period (hyper-indirect requirements). The main difference between the two approaches is that in the latter, each hyper-subsystem produces only final consumption goods, so that they are totally independent from one another.⁶ Their dynamics depend only on the growth rate of the consumption of the good they produce. On the contrary, vertically integrated sectors are not independent, as an evolution in the rate of consumption of a good i will impact all sectors producing capital goods that are required for the production of this good i (Garbellini and Wirkierman, 2014).

The previous approach of vertically integrated sectors has already been used in ecological economics. After reviewing this literature, I will show how the use of the more recent approach of hyper-subsystems improves these analyses.

4.1 Review of literature

Alcántara (1995) seems to be the first to use the vertically integrated approach for the analysis of pollution. His approach is simple: vertically integrated coefficients of pollution can be constructed just as vertically integrated coefficients of

⁶This also means that the number of hyper-subsystems, which is equal to the number of final consumption goods, is smaller than the total number of industries as soon as one industry only produces capital goods.

labor, once we know the pollution produced per unit of output by each industry. Sánchez-Chóliz and Duarte (2003) use this approach to analyze the pollution associated with the demand of one sector of production (which produces either consumption or capital goods). Alcántara and Padilla (2009) use the same approach to study the CO₂ emissions of the service sector in Spain and Butnar and Llop (2011) pursue their analysis with a study of the determinants of a change in CO₂ emissions, structural decomposition. Structural decomposition to understand the causes of change of atmospheric pollution from industry in Spain has been also investigated by Roca and Serrano (2007), using the NAMEA input-output accounting.

In Sanchez-Choliz and Duarte (2005), a slightly aggregated model is presented, each sector being composed of several different industries with different processes. They investigate changes in productivity and final demand, figuring how these changes impact the vertically embodied pollution of each sector. Furthermore, assuming constant returns to scale, they try to optimize the system depending on value added, pollution, and employment. They try to differentiate consumer responsibility from producer responsibility (this distinction is also implemented in Cadarso et al., 2010). Finally Cadarso et al. (2012) study the impact of international trade on the responsibility of pollution. They decide to account for the responsibility of the pollution depending on the share of net product value - i.e. added value - that goes to each country.

We should note that one of the problem highlighted by Sanchez-Choliz and Duarte (2005) is that investments are mixed with final consumption in their account of “final demand”. We actually find this problem in all the literature. Anticipation of changes in the structure of final consumption is not considered, whereas the investments required by this changing structure may actually explain a large part of the residual that appears in structural decomposition analyses made by Roca and Serrano, 2007 and Butnar and Llop, 2011. Hence, we can say that the different models presented in the literature are not really dynamic. They compare different static states, without properly taking into account how to manage the transition between those states.

If we want to take into account for each subsystem the evolution of final consumption and thus the investments required by its evolution, we should adopt the hyper-subsystem approach developed by Pasinetti (1988; 1989), where different rates of growth are attributed to each hyper-subsystem. In this way, the evolution of the pollution will be more precisely attributed to each component of final demand, at each period of production. Secondly, it will also prove useful for the integration of waste productions and natural resource needs, and for the study of the evolution of these productions and needs at each periods, relating them precisely with each component of final demand. In this way, we will move from static comparison to dynamic analysis.

4.2 Hyper-subsystems

Here I will follow the clear formulation given by Pasinetti (1988). Consider the rate of growth of the final consumption of one commodity i as:

$$g_i(t) = \frac{c_i(t+1) - c_i(t)}{c_i(t)} \quad (1)$$

With $c_i(t)$ the level of final consumption of commodity i at period t .

Our system of production of n commodities by means of commodities and labor organized within n industries can be described like this:⁷

$$\mathbf{A}(t) \mathbf{x}(t) + \mathbf{c}(t) + \mathbf{A}(t) \sum g_i(t) \mathbf{x}^{(i)}(t) = \mathbf{B}(t) \mathbf{x}(t) \quad (2)$$

$$\mathbf{a}_l(t) \mathbf{x}(t) = L(t) \quad (3)$$

$$\mathbf{A}(t) \mathbf{x}(t) = \mathbf{s}(t) \quad (4)$$

$$\mathbf{x}^{(i)}(t) = [\mathbf{B}(t) - (1 + g_i(t)) \mathbf{A}(t)]^{-1} \mathbf{c}^{(i)}(t) \quad (5)$$

$$\mathbf{s}^{(i)}(t) = \mathbf{A}(t) [\mathbf{B}(t) - (1 + g_i(t)) \mathbf{A}(t)]^{-1} \mathbf{c}^{(i)}(t) \quad (6)$$

$$L_i(t) = \mathbf{a}_l(t) [\mathbf{B}(t) - (1 + g_i(t)) \mathbf{A}(t)]^{-1} \mathbf{c}^{(i)}(t) \quad (7)$$

$$\sum \mathbf{c}^{(i)}(t) = \mathbf{c}(t); \sum \mathbf{x}^{(i)}(t) = \mathbf{x}(t); \sum \mathbf{s}^{(i)}(t) = \mathbf{s}(t); \sum L_i(t) = L(t) \quad (8)$$

Where $\mathbf{c}^{(i)}(t)$ is a column vector the n components of which are all zeros except the i^{th} one⁸. \mathbf{A} and \mathbf{B} are respectively the input and output coefficient inter-industry matrices, \mathbf{a}_l is the input labor coefficient row vector, $\mathbf{x}(t)$ is the industry intensity level column vector (i.e. the intensities at which the respective activities are carried on), $\mathbf{c}(t)$ the final consumption column vector, $\mathbf{s}(t)$ the means of production column vector, $L(t)$ the quantity of labor. The physical units are chosen so as to make the main diagonal of the output coefficient matrix \mathbf{B} a list of ones.

A unit of vertically hyper-integrated productive capacity for commodity i is defined as the i^{th} column $\mathbf{m}_i^\star(t)$ of matrix $\mathbf{M}^{(i)}(t)$, this latter matrix being defined in this way:

$$\mathbf{M}^{(i)}(t) = \mathbf{A}(t) [\mathbf{B}(t) - (1 + g_i(t)) \mathbf{A}(t)]^{-1} \quad (9)$$

The unit of vertically hyper-integrated productive capacity represents the commodities needed to maintain and expand the productive capacity of the final consumption commodity i , i.e. the commodities needed to produce one

⁷ Bold capital letters refer to matrices, bold lower case letters to vectors, italic letters to scalars.

⁸ Even the i^{th} component is equal to zero if industry i only produces capital goods.

unit of commodity i at period t the investments needed to produce $1 + g_i(t)$ units at period $t + 1$. We can note that $\mathbf{m}_i^\star(t) = \mathbf{s}^{(i)}(t)$ when $c_i(t) = 1$.

Similarly, we can define a vertically hyper-integrated labor coefficient for commodity i as the i^{th} component $l_i^\star(t)$ of row vector $\mathbf{l}^{(i)}(t)$, this latter vector being defined in this way:

$$\mathbf{l}^{(i)}(t) = \mathbf{a}_l(t) [\mathbf{B}(t) - (1 + g_i(t)) \mathbf{A}(t)]^{-1} \quad (10)$$

As for the price system, if we assume a uniform rate of profits $\pi(t)$, we have:

$$\mathbf{p}(t) \mathbf{A}(t) + \mathbf{p}(t) \mathbf{A}(t) \pi(t) + \mathbf{a}_l(t) w(t) = \mathbf{p}(t) \mathbf{B}(t) \quad (11)$$

With $\mathbf{p}(t)$ the price row vector and $w(t)$ the wage rate. If we assume non-uniform rates of profits, with $\pi_i(t)$ the rate of profits of industry i , we have:

$$\mathbf{p}(t) \mathbf{A}(t) + \mathbf{p}(t) \mathbf{A}(t) \mathbf{\Pi}(t) + \mathbf{a}_l(t) w(t) = \mathbf{p}(t) \mathbf{B}(t) \quad (12)$$

Where $\mathbf{\Pi}(t)$ is the diagonal matrix with the different rates of profits in the main diagonal.

4.3 Use for managing pollution

A matrix of pollution per industry, with one row for each different kind of pollution, can be easily added, so that the pollution related to the final consumption of one good and the investments required by the evolution of its final consumption, can be precisely described.

Consider $z_{ij}(t)$ as a pollution coefficient describing the amount of pollution i emitted during the process of production of one unit of commodity j , and a pollution matrix $\mathbf{Z}(t)$ with the same number of columns n than matrices \mathbf{A} and \mathbf{B} (it may have a different number of rows). Then the pollution directly, indirectly and hyper-indirectly caused by the production of the quantity c_i of commodity i can be represented in this way:

$$\mathbf{z}^{(i)}(t) = \mathbf{Z}(t) [\mathbf{B}(t) - (1 + g_i(t)) \mathbf{A}(t)]^{-1} \mathbf{c}^{(i)}(t) \quad (13)$$

We can thus define a unit of vertically hyper-integrated pollution $\mathbf{z}_i^\star(t)$ as the vector describing the amounts of pollution emitted during the process of production of one unit of consumption good i and the investments required by its consumption growth rate. We define it in this way: $\mathbf{z}_i^\star(t) = \mathbf{z}^{(i)}(t)$ when $c_i(t) = 1$.

On the value side, if a tax on the emission of a pollution is implemented and that $\mathbf{u}(t)$ is a vector summarizing all the taxes per emission, then the value system will be (if the rate of profits is uniform and if the taxes are paid at the end of the period of production):

$$\mathbf{p}(t) \mathbf{A}(t) + \mathbf{p}(t) \mathbf{A}(t) \pi(t) + \mathbf{a}_l(t) w(t) + \mathbf{u}(t) \mathbf{Z}(t) = \mathbf{p}(t) \mathbf{B}(t) \quad (14)$$

And if the rates of profits $\pi_i(t)$ are not uniform, the value system can be presented in this way:

$$\mathbf{p}(t) \mathbf{A}(t) + \mathbf{p}(t) \mathbf{A}(t) \mathbf{\Pi}(t) + \mathbf{a}_l(t) w(t) + \mathbf{u}(t) \mathbf{Z}(t) = \mathbf{p}(t) \mathbf{B}(t) \quad (15)$$

4.4 Use for managing natural resource extraction

In the same way, a matrix of natural resource extraction per industry, with one row for each different kind of natural resource, can be added very easily.

Consider $e_{ij}(t)$ as a natural resource extraction coefficient describing the amount of natural resource i that has to be extracted for the production of one unit of commodity j , and a natural resource extraction matrix $\mathbf{E}(t)$ with the same number of columns n than matrices \mathbf{A} and \mathbf{B} (it may have a different number of rows). Then the natural resources directly, indirectly and hyper-indirectly required by the production of the quantity c_i of commodity i can be represented like this:

$$\mathbf{e}^{(i)}(t) = \mathbf{E}(t) [\mathbf{B}(t) - (1 + g_i(t)) \mathbf{A}(t)]^{-1} \mathbf{c}^{(i)}(t) \quad (16)$$

We can thus define a unit of vertically hyper-integrated natural resources extraction $\mathbf{e}_i^\star(t)$ as the vector describing the quantities of natural resources extracted to produce one unit of consumption good i and the investments required by its consumption growth rate. We can define it in this way: $\mathbf{e}_i^\star(t) = \mathbf{e}^{(i)}(t)$ when $c_i(t) = 1$.

On the value side, if a rent on the extraction of a natural resource is implemented and that $\mathbf{r}(t)$ is a vector summarizing all the rents per natural resource extraction, then the value system will be (if the rate of profits is uniform and if the rents are paid at the end of the period of production):

$$\mathbf{p}(t) \mathbf{A}(t) + \mathbf{p}(t) \mathbf{A}(t) \pi(t) + \mathbf{a}_l(t) w(t) + \mathbf{r}(t) \mathbf{E}(t) = \mathbf{p}(t) \mathbf{B}(t) \quad (17)$$

And if the rates of profits $\pi_i(t)$ are not uniform, the value system can be represented in this way:

$$\mathbf{p}(t) \mathbf{A}(t) + \mathbf{p}(t) \mathbf{A}(t) \mathbf{\Pi}(t) + \mathbf{a}_l(t) w(t) + \mathbf{r}(t) \mathbf{E}(t) = \mathbf{p}(t) \mathbf{B}(t) \quad (18)$$

4.5 Use for capability

Finally, following the suggestion made by Martins (2016; 2018), we could link Sraffian ecological economics and the capability approach by defining a vector of subsistence commodities $\mathbf{d}(t)$, that would provide each member of a population $N(t)$ the access to a specific standard of living, which is socially defined as the minimum standard. This vector will connect the classical concept of

“subsistence wage” and Nussbaum’s concrete view on capabilities, where the focus is on objective functionings to be achieved by means of a finite quantity of commodities.

From our formal system, we can know the value of the subsistence wage:

$$r_{min}(t) = \mathbf{p}(t) \mathbf{d}(t) \quad (19)$$

We can also compute the part of the subsistence wage in the national revenue:

$$C_{basic}(t) = N(t) \mathbf{p}(t) \mathbf{d}(t) \quad (20)$$

And finally we can define the minimum wage rate (or wage per hour) below which no one will be able to earn the subsistence wage at the end of the year:

$$w_{basic}(t) = \frac{N(t) \mathbf{p}(t) \mathbf{d}(t)}{L(t)} \quad (21)$$

To sum up, from the technologies of production, the industry intensity levels, the rates of profits in the different industries, and the way the national wage is shared in the different industries, we can know the prices and the wage rate. Hence, if we can define a set of subsistence commodities, we will find their prices at the current level of distribution. We will be also able to define the minimum wage per capita and per year, at this level of distribution, as well as the minimum wage rate. With this, we can know if enough subsistence commodities are produced to guarantee the access of each capability for all, and, knowing the wage earned by each individual, we can know the number of individuals that cannot afford all the subsistence commodities, and must make dramatic choices (Walsh, 2003).

If we want to avoid dramatic choices, several options are possible: we can change the distribution of the national revenue so that each individual receives at least the subsistence wage, or we can increase production so that enough subsistence commodities are produced for everybody, or we can decrease the cost of production of the subsistence commodities by technological change. In order to decide between these options, it may be interesting to know the emissions linked with the production of the subsistence commodities and the evolution of their consumption, as well as the extraction of natural resources needed to produce this set and to increase or decrease its production. They can be calculated in the following way:

$$\mathbf{e}_{basic}(t) = N(t) \sum_{i=1}^n \mathbf{E}(t) [\mathbf{B}(t) - (1 + g_i(t)) \mathbf{A}(t)]^{-1} \mathbf{d}^{(i)}(t) \quad (22)$$

$$\mathbf{z}_{basic}(t) = N(t) \sum_{i=1}^n \mathbf{Z}(t) [\mathbf{B}(t) - (1 + g_i(t)) \mathbf{A}(t)]^{-1} \mathbf{d}^{(i)}(t) \quad (23)$$

5 Concluding remarks

With this representation of hyper-subsystems, we are more precisely allocating pollution and natural resource extraction to each component of final demand, by taking explicitly into account the investments required by the evolution of final demand. But this does not mean that we are taking all environmental problems into consideration. In particular, pollution during the process of consumption is not considered (private house consumption of energy and water, or private car atmospheric pollution, etc.). Only the responsibility of the production side is considered. Nevertheless, this investigation can facilitate the construction of scenarios on the evolution of the production process or in the composition of demand in order to increase the universal access of basic capabilities, while decreasing our impact on the environment.

The hyper-subsystem approach is thus a tool showing that Sraffian ecological economics can have a constructive side. It furthermore reveals that the capability approach can be included in the development of this constructive side. Sraffian ecological economics, if it proves itself useful as an heterodox school, should also develop its critical side. But the hegemony of neoclassical theory will not be challenged by criticism only. The construction of an epistemological, ethical, and ontological proposal, linked with the development of concepts and tools useful for theoretical and empirical studies is thus a really important part of a program that would seek to develop Sraffian ecological economics.

Martins (2018) is thus right when he criticizes Verger (2017b) by saying that the focus in this article was too much on the critical side of Sraffa's theory, overlooking Sraffa's objective approach that can lead to interesting constructive ideas. However, his use of the concepts of Standard commodity and Standard system does not seem to me to be appropriate, as well as his suggestion that some developments may only be of theoretical interest, while not being of any practical use. I believe that the Standard system and the Standard commodity are currently more useful on the critical side of Sraffian ecological economics and I hope to have shown that Sraffa believed that a good theory was a one that could be used on empirical level.

It is important to note that this article provides only the first steps for a long research project. I do believe that the journey must be done, even though I do not know where it will lead us.

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