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► **To cite this version:**

| Yoann Verger. Sraffa and ecological economics: review of the literature. 2015. hal-01182894

**HAL Id: hal-01182894**

**<https://hal.science/hal-01182894>**

Preprint submitted on 5 Aug 2015

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## Chapter 1

# Sraffa and ecological economics: review of the literature

References to Sraffa and to the neo-Ricardian school is something quite customary in ecological economics. By looking at contributions in this area since the beginning of ecological economics and at contributions on environmental problem from the neo-Ricardian school, we see that a connection between both school still has to be made. This connection should be articulated around the initial aim of Sraffa: to develop a new paradigm, competing against the neoclassical one. Only then it will be possible to develop a real eco-Sraffian approach able to pursue the analysis of the sustainability of the economic system.

This review of the literature is divided in three sections. Section 1 describes the part of the literature engaged in the “valuation of nature” debate; section 2 the works of researchers trying to develop a neo-Ricardian approach of ecological conflicts; and section 3 several works trying to use the neo-Ricardian knowledge in the analysis of physical interdependence between processes, in particular for the assessment of CO<sub>2</sub> emissions. In each of these last sections, works are presented in a (more or less) chronological way.

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## 1.1 The first direction: monetary valuation of the environment, energy theory of value

### 1.1.1 GEORGESCU-ROEGEN

This debate about the valuation of ecosystem resources and services is a very old one. In an interview with Pellegrini (2012), Martinez-Alier recalls that we can find its beginning in the debate between Wilhelm Ostwald (1908)<sup>1</sup> and Alfred Weber (1909) in the beginning of the XX<sup>th</sup> century. Ostwald is one of the first to argue that a strong relationship exists between the use of energy and economic growth. But, from that, he does not deduce any theory of value and explicitly warns that this would be impossible: “we would err if we measured value only in proportion to the amount of free energy” (Ostwald (1908), p. 164). Weber answers that the determinant of action at the micro-level is profitability, and not energy efficiency. This debate is carried on later by Neurath (1973), Von Mises and Hayek (1952). Neurath says that it is impossible to base decisions on prices about the use, or not, of non renewable natural resources, as it is impossible to know their future utility for future generations, whereas for Von Mises, prices express rationality and help to ensure an efficient allocation of resources and consumption goods, even in an intertemporal way. Hayek adds to Von Mises point of view a strong criticism of the social engineering of Saint Simon, but also of Neurath, as the reject of prices as efficient indicators for the management of natural resources leads to social planning of production, and thus, for Hayek, to dictatorship<sup>2</sup>.

This debate is then revive by the birth of what Georgescu-Roegen calls the new “energetics” dogma (Georgescu-Roegen (1979)). Researchers such as Fred Cottrell (Cottrel (1953)), H. T. Odum (Odum (1973, 1977); Odum and Odum (1981)), Harrison Brown (Brown (1954); Brown et al. (1957)), Alvin Weinberg, Glenn Seaborg and (even if he relaxes his position later on) Kenneth Boulding (Boulding (1966)) believe that all physical exchanges can be reduced to energy exchange and that, if the input flow of energy is big enough, it would be possible to recycle all material flows inside the economy and effectively build a Space-ship Earth economy. From that, some of them (e.g. Gilliland (1975-1976); Slessor (1975)) say that an energy theory of value could be constructed where energy would be the economic unit of value (British thermal unit (BTU) for

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<sup>1</sup>Ostwald was part of group of researchers, including Ernest Solvay, George Helm, Pierre Duhem and Frederick Soddy (1926), following the work of Ernest Mach; for them, “matter must in the ultimate analysis reduce to the only 'substance', energy” (Georgescu-Roegen (1979)). They were the firsts to say that economy cannot violate thermodynamics laws.

<sup>2</sup>My point of view on this debate is that Weber is right when he says that the determinant of action at the micro-level is profitability; but at the macro-level, the consequence of economic growth is indeed an increasing energy consumption (Ayres et al. (2013)). Von Mises is right when he says that prices can help to allocate scarce resources, but only in situations with no uncertainty, no future generations and with a perfect and fair initial distribution of revenue. Finally Hayek is right to criticize the dictatorial vision of Saint Simon, but he is wrong if he thinks that the actions of free agents engenders always the optimal society. For me, Ostwald and Neurath defends the right position that the economic way of assigning exchange value can not work for the assessment of natural resources values.

instance, instead of dollars). Their point is that, if all physical exchanges can be reduced to energy exchanges, it could be possible to reduce also money exchanges. Then the efficiency of an economic system should be measured by looking at the amount of energy needed to produce a given amount of money instead of looking at the amount of money produced per capital.

But to measure this efficiency one must account how much energy is needed by the system. And there arise some controversies about:

- should we take into account the energy consumed by human labor?
- should we take into account the amount of energy available outside the economic system (gross energy analysis, e.g in Cottrel (1953); Odum (1973))?
- or should we take into account only the amount of energy available in usable form for the economic system, i.e. after extraction (net energy analysis, e.g. in Chapman et al. (1974); Price (1974); Slesser (1977))?<sup>3</sup>

Georgescu-Roegen strongly stand against the new “energetics” dogma, arguing that:

1. Energy matters but matter matters too, in two important ways. First it is not possible to create all materials from energy as only the big-bang created proton and neutron from energy alone : “certainly, we can also convert energy into additional mass, but only in very special cases (usually, in laboratory installation) and in relatively small amounts and not into *nucleon* mass” (Georgescu-Roegen (1979)). Second, matters, like energy, is continuously lost for human use : “all over the material world there is rubbing by friction, cracking and splitting by changes in temperature or evaporation, there is clogging of pipes and membranes, there is metal fatigue and spontaneous combustion” (Georgescu-Roegen (1979)). Both arguments explain why complete recycling of matter is not possible (Georgescu-Roegen calls this the Fourth Law of Thermodynamics or “Law of Matter Entropy”)<sup>4</sup>, and thus why the new “energetics” dogma is

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<sup>3</sup>This last proposal is thus concerned only about efficiency within the system, and not about the efficiency of the link between the environment and the economy, which is important in the gross energy analysis. Apart from these questions, these researchers inside the new “energetics” dogma do not move away from the neoclassical paradigm as they think that utility (use value) can be measured on money terms (exchange value). They also ignore the warning given by Ostwald that an energy theory of value does not mean anything.

<sup>4</sup>Cleveland and Ruth (Cleveland and Ruth (1997)) records some arguments against this Fourth Law. For instance, “well-documented counter examples to Georgescu-Roegen’s Fourth Law include the biogeochemical cycles — driven by the influx of solar radiation — that constantly funnel dissipated materials through a closed, global ecosystem and temporarily generate high material concentrations. It is those processes that lead to the formation of pearls from ocean water in the first place, the agglomeration of metals in ores and the formation of fossil fuels” (Cleveland and Ruth (1997)). Cleveland and Ruth defend the Law by arguing that even if we can find some counter examples in nature, there is no counter example in a time frame relevant to the human economy: “biological systems ... differ markedly from economic systems with regard to the time available to trace, collect and upgrade materials. Ore deposits and fossil fuels have been formed over time periods that are far too long to be of relevance for economic decision making. ... Thus, from an economic perspective, an increasing dispersal of materials is constraining as long as tracing, collecting and upgrading those materials requires expenditures of finite, costly sources of low-entropy energy” (Cleveland and Ruth (1997)).

wrong: an economic system cannot but exchange energy *and matter* with the environment.

2. Economy is not just about production of commodities, but also about distribution of the surplus: this distribution influence the economic value of commodities. But the issue of distribution can not be tackled by an energy theory of value (or an “energy+matter” theory of value). To explain this point Georgescu-Roegen constructs a simplified flow-fund economic system. Flows are the exchanges of energy and materials between industries. Funds are “the agents that performed the change” (Georgescu-Roegen (1979)): these agents are human labor, capital and land. Funds must be represented because “in any economic system both the quantities represented by the flow elements *and* the services provided by the agents have value” (Georgescu-Roegen (1979)).<sup>5</sup> And this is the main difference with economic systems constructed by the partisans of the new “energetics” dogma. In their models, only exchanges of energy (and/or matter) are represented. Thus services provided by the agents have no value, apart from the energy spent producing this service. Then the political struggle about the value of services such as human labor or capital and land loans, is not represented and the distribution of the surplus have no influence on the energy price.

Let us describe this flow-fund economic model where, as a starting hypothesis, Georgescu-Roegen assumes that only energy is exchanged with the environment. There are 5 economic processes: process 1 creates controlled energy (*ce*), material waste (*w*) and dissipated energy (*d*) from capital (*k*) and energy in situ (*es*), process 2 creates capital, material waste and dissipated energy from controlled energy and recycled matter (*rm*), process 3 creates consumption goods (*c*), material waste and dissipated energy from controlled energy, capital and recycled matter, process 4 creates recycled matter and dissipated energy from controlled energy and capital and finally there is a process 5 of consumption, creating only material waste and dissipated energy from controlled energy and capital. All processes are using furthermore the stocks of Capital Equipment (*K*), People (*H*) and Ricardian Land (*L*).

The model can be represented like this, with **A** the input matrix and **B** the output matrix, processes in column and resources in row:

$$\mathbf{A} = \begin{bmatrix} 0 & ce_2 & ce_3 & ce_4 \\ k_1 & 0 & k_3 & k_4 \\ 0 & 0 & 0 & 0 \\ 0 & rm_2 & rm_3 & 0 \end{bmatrix} \quad (1.1)$$

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<sup>5</sup>Here I disagree with Georgescu-Roegen: services provided by the agents (i.e. “funds” for Georgescu-Roegen) have value (and thus influence the value of all goods) because the agents *claims that they have value*. They do not have value by themselves, there is no intrinsic value of such services: we could imagine an economic system where some funds have no value (land for example).

$$\mathbf{B} = \begin{bmatrix} ce & 0 & 0 & 0 \\ 0 & k & 0 & 0 \\ 0 & 0 & c & 0 \\ 0 & 0 & 0 & rm \end{bmatrix} \quad (1.2)$$

The inputs of the production process are represented in the column vector  $\mathbf{c}$ :

$$\mathbf{c} = \begin{bmatrix} ce_5 \\ k_5 \\ c_5 \\ 0 \end{bmatrix} \quad (1.3)$$

The production of material waste is represented by the row vector  $\mathbf{w}$ :

$$\mathbf{w} = [ w_1 \quad w_2 \quad w_3 \quad 0 \quad w_5 ] \quad (1.4)$$

The production of dissipated energy is represented by the row vector  $\mathbf{d}$ :

$$\mathbf{d} = [ d_1 \quad d_2 \quad d_3 \quad d_4 \quad d_5 ] \quad (1.5)$$

The inputs of energy in situ is represented by the row vector  $\mathbf{es}$ :

$$\mathbf{es} = [ es_1 \quad 0 \quad 0 \quad 0 ] \quad (1.6)$$

The funds of Capital, People and Land are represented by the row vectors  $\mathbf{k}$ ,  $\mathbf{h}$  and  $\mathbf{l}$ :

$$\mathbf{k} = [ K_1 \quad K_2 \quad K_3 \quad K_4 ] \quad (1.7)$$

$$\mathbf{h} = [ H_1 \quad H_2 \quad H_3 \quad H_4 ] \quad (1.8)$$

$$\mathbf{l} = [ L_1 \quad L_2 \quad L_3 \quad L_4 ] \quad (1.9)$$

Starting with net energy analysis, he tries to find a definition for net energy : “Four possible definitions of net energy seem to deserve attention: a)  $[ce]$ ; b) the difference between  $[ce]$  and the energy equivalent of  $[k_1]$ ; c)  $[ce_5]$ ; and d)  $[ce_5]$  plus the energy equivalent of  $[k_5]$  and  $[c_5]$ ” (Georgescu-Roegen (1979)). Definitions a) and c) are discarded and definitions b) and c) lead to the same result. Defining  $e_i$  as the “energy equivalent per unit of flow product” of resource  $i$  and  $\mathbf{e}$  the row vector with all  $e_i$  as components, we find the Net Energy  $NE$  by solving the following system of equations:

$$\mathbf{eB} = \mathbf{eA} + [ NE \quad 0 \quad 0 \quad 0 ] \quad (1.10)$$

As the energy equivalent per unit of flow product of controlled energy is equal to one, energy is the numeraire of the system. Georgescu-Roegen notes that if the material waste is to be accounted, through energy equivalence, as a

joint product in each process, the system of energy price becomes undetermined (as there is more resources than processes).

Then Georgescu-Roegen looks at the gross energy analysis: here the system of energy price (with a new vector  $\mathbf{e}'$ ) becomes:

$$\mathbf{e}'\mathbf{B} = \mathbf{e}'\mathbf{A} + \mathbf{e}s \quad (1.11)$$

The two systems 1.10 and 1.11 are thus closely related. The numeraire in the second system is given by the unit in which energy in situ is measured. Thus the relation between both system is simply:

$$NE = \frac{es_1}{e'_1} \quad (1.12)$$

In both cases, the surplus is converted into energy equivalent, and then distributed to the owner of the energy in situ resource.

Then turning to economic valuation, Georgescu-Roegen says that services, arising from the stocks, influence values. The system of prices is then:

$$\mathbf{pA} = \mathbf{pB} + p_K\mathbf{k} + p_H\mathbf{h} + p_L\mathbf{l} \quad (1.13)$$

Georgescu-Roegen further adds “the equation of the national budget”:

$$\mathbf{pc} = [p_K\mathbf{k} + p_H\mathbf{h} + p_L\mathbf{l}] \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \quad (1.14)$$

Thus there is no proportionality between the energy system of value and the economic system of value, unless two of the three distributional variables  $p_K$ ,  $p_H$  and  $p_L$  are set to zero. And Mayumi (Mayumi (2001), p.71)<sup>6</sup> shows that, if we have a rent  $R$  on energy in situ, there is no proportionality as soon as one distributional variable is different from zero, because the system of price becomes:

$$\mathbf{pA} = \mathbf{pB} + Res + p_K\mathbf{k} + p_H\mathbf{h} + p_L\mathbf{l} \quad (1.15)$$

Mayumi compares also Georgescu-Roegen’s and Sraffa’s models (Mayumi (2001), p.71-72, Mayumi and Tanikawa (2012)). There are two main differences:

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<sup>6</sup>Mayumi looked at empirical applications of the flow-fund model of Georgescu-Roegen and in order to do that developed the Multi-Scale Integrated Analysis of Societal Metabolism (MSIASM, Gowdy et al. (2009)). The goal is to look at societies through the lense of their use of human labor and exogenous energy. These two inputs are considered as “primary inputs”, but the human labor is seen as a fund, thus “requiring investment at reproduction” (Gowdy et al. (2009)). Indexes such as “the saturation index of human labor” can be deduced, at the national or sectoral level.

- fixed capital is a fund for Georgescu-Roegen, which depreciates and is nourished by a single process (at each period the value of the capital produced is equal to  $p_2k$ , and this value is equal to the depreciation of capital if we are in a stationary state) whereas it is a set of different commodities for Sraffa, as machines with different ages are different commodities.
- The profit is seen as a rent on capital, in order to pay for the service of the capital fund, whereas in Sraffa the profit is a rate of return for a process (there is no payment for any “service”, the origin of profit lies in the production of a surplus).

### 1.1.2 COSTANZA

Costanza (Costanza and Neill (1981)) looks at the relation between the economy and the environment from the point of view of “energy-value”. He constructs a model designed to compute the costs of the production of each good in terms of solar energy (which he calls embodied solar energy). He wants explicitly to compute prices.

He chooses a joint production system with  $m$  processes and  $n$  goods, defined by the following value system (Costanza (1980); Costanza and Neill (1981)) :

$$\mathbf{E} + \mathbf{e}\mathbf{A} = \mathbf{e}\mathbf{B} \tag{1.16}$$

With  $\mathbf{A}$  and  $\mathbf{B}$   $n \times m$  matrices of constant technical coefficients corresponding respectively to the inputs and the outputs (real quantities from year 1970),  $\mathbf{E}$  the  $m$  line vector of direct solar energy inputs and  $\mathbf{e}$  the  $n$  line vector of prices in terms of energy-value. If  $m = n$ , we can solve the system :

$$\mathbf{e} = \mathbf{E}(\mathbf{B} - \mathbf{A})^{-1} \tag{1.17}$$

We can see that we have an analogy with Sraffa’s system when  $w = 1$  and  $\pi = 0$ . The problem is that this system does not always compute only positive prices: indeed, in single production systems, the only positive coefficients of matrix  $\mathbf{B} - \mathbf{A}$  are on the main diagonal, and this is why the inverse matrix is always positive. In joint production systems, we can found positive coefficients aside from the main diagonal.

In a following model, Costanza and Neill (Costanza and Neill (1984)) adopt a linear programming point of view. They assume that ecosystems want to maximize the surplus, valued in terms of energy-price:

$$\mathbf{e}\mathbf{Y} \tag{1.18}$$

With  $\mathbf{Y}$  the vector of net exports, given in an exogenous way and expressed in physical quantities, knowing that :

$$\mathbf{e}(\mathbf{B} - \mathbf{A}) \leq \mathbf{E} \tag{1.19}$$

$$\mathbf{e} \geq \mathbf{0} \tag{1.20}$$



The initial available energy ( $\mathbf{E}$ ) is given in an exogenous way (as are given initial quantities  $\mathbf{Q}$  in this kind of neoclassical systems), energy-prices ( $\mathbf{e}$ ) represents scarcity indexes (like rent-prices  $\mathbf{r}$ ) in relation to an exogenous demand ( $\mathbf{Y}$ ) (equivalent to demand  $\bar{\mathbf{p}}$ ) and the goal of revenue maximization allows the choice of the best available techniques. This model is applied for an ecosystem without economic process (Costanza and Neill (1984)).

But soon thereafter, Costanza and Hannon (Costanza and Hannon (1989)) go back to a system where economic and environmental processes are interdependent, with again equation 1.16. They draw an analogy between economic and ecological systems to justify the fact prices are unique for each good within the system, saying that the ecosystem reacts as if it were in a state of perfect competition:

“for a system to be competitive in this sense, it must have many, small consumers and producers each possessing all the current information about the variables which affect them. Under these conditions, no single consumer can directly affect the unit weight of a commodity” (Costanza and Hannon (1989)).

Then again negative values can appear because of joint production, but “these negative intensities are most likely the result of poor data or poor system specification, and can be eliminated by better data or better specification of the system” (Costanza and Hannon (1989)).

They furthermore come up with the question of the value system if more than one net input is found:

“consider an ecosystem with boundaries defined such that there are net inputs of both sunlight and water. In such a case we would calculate sunlight intensities and water intensities but we would have no way of comparing or adding the two” (Costanza and Hannon (1989)).

They accordingly choose to consider the largest system possible, Earth, where the only net input is solar energy. They are then able to compute the energy-price of one liter of water and of one dollar of manufactured product.

Some questions appears:

1. Is it possible to have a theory of value without a theory of distribution?
2. How and why can we compare two systems of value?
3. Why choosing the solar energy value?

### 1.1.2.1 Distribution

Wage, profit and rent are the three distribution variables influencing prices through the share of the net surplus in Sraffa's system. Concerning the environment, there is no distribution because there is no exchanges (and then

no need for prices). Solar energy values represent quantities of solar energy directly and indirectly required to produce each good, i.e. it is the exact equivalent to vertically integrated labor coefficients in the case of the labor theory of value (where profit is equal to zero). Then if they were to be a distribution of the net surplus in this energy value system, all surplus would have come to the owners of the energy inputs (it is the same thing to say that prices reflects cost of production in energy terms).

### 1.1.2.2 Comparing 2 systems of value

The goal of comparing two systems of value is to assess relative importance of some processes or of some goods: for instance, in this system of value, this process weights a lot, in this one he is considered to produced no value added. Then we can qualitatively compare 2 systems of value: but is there a need to do a quantitative analysis? Costanza explains that it would be interesting to give a quantitative value to nature: “the potential utility to environmental managers and decision makers of defendable answers to questions like : what is the true extra-market value of rainfall? or ecosystem services? or non-renewable resources? is enormous” (Costanza and Neill (1981)).

How is this quantitative analysis built? From an Input-Output table with the yearly flows of environmental resources (biomass, nitrogen, carbon dioxide, phosphorus, water vapor, liquid water, fossil energy), he deduces their energy prices, or their solar energy costs of production. In the table, two processes are economic ones : agricultural production, with an output measured in mass, and economic production, with an output measured in GNP, i.e. in dollars. Then he can compute the price of the production of one dollar in terms of energy, and he can go backward to compute the price in dollar of all natural resources.

For instance, he can compare the energy price of pound of agricultural production and the energy-price of one dollar:  $\frac{\text{energy-price}_{\text{pound}}}{\text{energy-price}_{\text{dollar}}} = 0,03$ . We get an exchange ratio between these two goods, in terms of energy cost of production: production of 0.03 dollars costs as much energy as the production of one pound of agricultural product. And we can reverse it: the production of 33 pounds of agricultural product cost the same amount of energy than the production of one dollar. The dollar is in this system the equivalent of pounds, i.e. a *physical* unit. We can exchange the physical quantity *one dollar* with the physical quantity *33 pounds of agricultural products*. And we can do the same for all other natural resources.

We can model the cohabitation in the system of Costanza (Costanza and Neill (1981), Costanza and Hannon (1989)) of dollar-prices and energy-prices in the following way:

$$\mathbf{E} + \mathbf{eA} = \mathbf{e(D_pB)} \quad (1.21)$$

With  $\mathbf{D_p}$  the diagonal matrix containing in his main diagonal prices  $p_{ii} > 0$ ,  $i = 1, \dots, k$  in dollars for en dollar for economic resources and prices  $p_{ii} =$

1,  $i = k + 1, \dots n$  for natural resources. Thus energy prices depends on the system considered, and this system (the coefficient of production) change when the dollar value of economic goods change.

### 1.1.2.3 Why the energy value?

Energy value is justified by Costanza because “the earth’s hydrologic, geologic and nutrient cycles, and net primary productivity all depend on the planet’s only significant net input - solar energy - to drive them” (Costanza and Neill (1981)) ; thus, energy-price is a measure of the dependence for each good on the initial energy input. For Costanza, energy is a limiting factor, but in the same time a determinant for action: “available energy both limits and governs the structure of humans economy” (Costanza (1980)). By comparing the cost of production of one dollar in terms of energy for different sectors of the American economy, he shows that this cost is approximately constant: then he deduces that economic value is in relation to energy use.

In fact, he shows that factors of productions (labor, capital, earth, energy) are interdependent and complementary: we cannot create value without energy, there could not be any substitution between, for instance, capital and energy (which is a discredit for the neoclassical theory of value). But the next step of his reasoning is more problematic. He chooses the pure theory of energy value, making a conscious parallel with the pure theory of labor. But he prefers the first one, because it is based on the only exogenous input of the Earth system, i.e. solar energy:

“The question might be asked whether the same thing we have done with energy could not be done with any of the other currently defined primary factors and thus support capital, labor, or government services theories of value. The answer is that on paper this could be done. We must look to physical reality to determine which factors are net inputs and which are internal transactions. No one would seriously suggest that labor creates sunlight” (Costanza (1980)).

Costanza goes further in this direction by considering that there is no conflict between the energy theory of value and the utility theory of value: in his system dollar prices are related to individual utility. But a contradiction arises: by showing that there is an empirical relation between dollar prices and energy-prices, Costanza seems to show that market prices gravitates around prices of production. So, curiously, he empirically proves that the price of production theory is correct, but nevertheless sticks to the utility theory to explain market prices (Costanza (1980)). This can be only logical if utility itself is reduced into a quantity of energy (Burkett (2006), p. 40).

As there is a relation between energy-value and dollar, he thinks that someone can deduce the prices of environmental resources, even if they are outside the market (“shadow prices”):

“with the appropriate boundaries, embodied energy values are accurate indicators of market values where markets exist. Because they are based on physical flows, they may also be used to determine ‘market values’ where markets do not exist - for example, in ecological systems” (Costanza (1980)).

In his accounting system, we can of course express the value of environmental resource compared to the value of economic production: but what is the point of this system of value, apart from showing the constraints on production because of the solar energy limited quantity?

The problem Costanza wants to solve is to define if it is economically profitable to destroy or to conserve a given ecosystem. What he is trying to say is that it is not because there is no human production that there is no production at all. He enlarges the price of production theory by assuming that the Sun is the driving motor behind all processes of production. Then the exchange value is dependent on the energy cost of production. And we can find the money value by dividing the amount of ecosystem one unit of energy can buy with the amount of dollar the same unit of energy can buy. One consequence is that if the economy improves its energy efficiency, the price of the ecosystem will decrease.

But Costanza does not initially want to work with dollar values:

“physical flow I-O data would be preferred for embodied energy calculations, but are not available in the required form at the national level. Calculations made with financial data are nevertheless useful, because they yield information on the direct and indirect energy required to produce a dollar’s worth of each of the commodities in the economy” (Costanza (1980)).

What would have happened if embodied energy data are found? He would have two systems of value. One where the surplus goes entirely into the pocket of the sun (energy theory of value), one where the surplus is shared between capitalist, workers and rentiers (Sraffa’s system). The first system is interesting to understand the pressure on the environment because of the specific technique used and the specific consumption pattern. This analysis is actually also possible (it is not because we are looking at marketed goods and services that the physical relations are not relevant for assessing the dynamics of the system) but add to that the possibility of analyzing the social conflict around the appropriation of surplus value.

### 1.1.3 CHRISTENSEN

Christensen (1987) thinks that “the negentropic material and energy flows from geological and biological production systems [...] are the true ‘basics’ of economic activity”. He wants to build a physical theory of production and thinks that the beginning of it can be found in the Classical theory, and particularly in Sraffa’s analysis. But he complains that, in those theories, energy is not

taken into account and that there is not enough focus on material and energy constraints:

“Sraffa (1960) contrasted Quesnay’s (and the classical’s) ‘picture of the system of production and consumption as a circular process’ with ‘the view presented by modern (neoclassical) theory of a one-way avenue that leads from ‘Factors of production’ to ‘Consumption goods’” (p. 93). The entropic character of resource use suggests that each of these pictures is incomplete. Dissipation of available energy imposes a one-way direction on processes that otherwise have the character of circular pathways or loops” (Christensen (1987)).

In a second article Christensen (1989), Christensen starts by criticizing the widening gap between reality and economic thinking: economists do not pay attention to economic facts. He wants to add facts and theories from “physics, chemistry, biology and ecology” in order to build “the biophysical foundations of economic activity”. A switch from physical facts to abstract theory and “analytical mechanics” can be seen as early as in Ricardo’s work on land, “which is expressly defined as a factor immune to any qualitative change (which) we could refer to simply as space” (Georgescu-Roegen (1971), cited in Christensen (1989)). At least Sraffa’s model can be seen as having biophysical foundations, because there is the need of basic commodities, which could be raw materials and food<sup>7</sup>, to run the model. Furthermore Christensen argues that the neo-Ricardian theory is interesting because prices are “reproduction prices”, i.e. “they are formulated to ensure the replication of the components of the social-economic system through time”<sup>8</sup>. But in this theory, there is no valuation of the environment: Christensen suggests that reproduction prices could apply also to environmental resources and services. And Christensen complains that material and energy balances are not introduced:

“I first realised the need to apply the principles of the conservation of matter and energy to production and the entropy law in the April of 1976 when I was completing my dissertation and realised that Sraffa’s production system lacked any physical specification of the material and energy flows required to produce commodities. A closed production system cannot reproduce itself” (Christensen (2005))<sup>9</sup>.

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<sup>7</sup> Sraffa actually does not say anything about the nature of his basic commodities.

<sup>8</sup> Actually this is a bit badly said, because prices does not ensure anything. This are the price that ensure the same production for the next period, but for the next period only. And they may not take into account important components for the sustainability of the system.

<sup>9</sup> Christensen overlooks the point that Classical economists were thinking in these terms: who should get a return on the produced added value? The central question was for them distribution, not the physical limits of production. For instance, he disagrees with Stuart Mill (1848) when the latter discards the distinction between energy and materials, and put them in the same heading, “materials” (Mill had a discussion on this point with Senior (1848), who was more willing to make this distinction because energy is not embodied into the produced good, as opposed to materials). There was no reason for Mill to make such distinction, as he

But his main criticism goes against the neoclassical framework, as it focuses less on the condition of production, and more on exchange optimization. Thus the whole neoclassical theory of value becomes to contradict physical facts. For instance the notion of marginal productivity is in conflict with the way real system of production operates: there is strong interdependence between factors of production rather than independent productivity for each of them:

“the notion of marginal productivity adopted by the early neoclassicals violates the fundamental scientific principles governing material and energy transformations ... The founding proposition of neoclassical economics, the principle of marginal productivity, is inconsistent with a scientific understanding of physical processes. And, as Schumpeter, Hicks and others have noted, without marginal productivity, there is no neoclassical theory” (Christensen (2005)).

All the early neoclassical authors (Jevons (1871); Menger (1871); Walras (1874); Marshall (1890)) thinks in terms of substitution between factors of production, without paying attention about complementarities and mass and energy balances. They have been misleading by the Ricardian treatment of land, where an increase of the labor input alone could lead to an increase of production. But this is actually only possible because some inputs (energy and materials) are not taken into account: in the real world, when the use of one input is increased, the output is not always increased, so marginal productivities cannot always be calculated. This mistake leads to the affirmation that distribution should be related to marginal productivity of only a few primary factors which can be substituted without constraint (Wicksteed (1894)).

Then the neoclassical theory of price can be relaxed from the observation of natural resource stocks and flows, technology development and constraints, etc., and concentrate only on initial endowments and consumers preferences. But, for Christensen, consumers preferences are not a good way to price natural resources:

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was thinking in terms of political economy; but, for Christensen, this was a mistake because he is thinking in terms of energy and material balances. He wants to look at the connection between the consumption of material and energy and the production of wealth, whereas Mill wonders who produces the wealth and how the distribution of wealth is achieved.

Sraffa also was not focusing on the feasibility of the physical loop, but on the value created by the system of production. The question Sraffa is trying to answer is: can we determine the exchange relations (price) with just data about inputs and outputs? Here there is two possibilities: or we assume that only marketed goods enters into the equations (this my position, as Sraffa explicitly says that he was concerned about commodities sold on the market), or we assume that, as Sraffa does not want to introduce demand in his model, he does not know what produced commodity is a good or a bad (but actually Sraffa never says that demand was not included in his model, cf. Sinha (2007)).

My position is that Sraffa's prices express the exchanges needed to reproduce the system. But this reproduction may not occur in reality as the only exchanges taken into account are exchanges of marketed commodities and services: of course the economic system is an open one, with wastes rejection and natural resources extraction. But they do not necessarily have a price, because they are not marketed commodities. They could, a rent can be stated on a land, and a tax can be asked for each waste disposal: only then they can be accounted in Sraffa's model.

“since there is no way of discerning the preferences of unborn generations, this leaves us with the dictates of the market and the subjective judgments of the present generation as to the values which should be placed on resources and natural environments” (Christensen (1989)).

So behind his critique of the neoclassical theory of value, his goal appears: he wants to put a value on the environment so that its use can be decided. He acknowledges that prices cannot be a guide for taking care of the natural resource (because of “uncertainty about future demand (including those of future generations), technological change, size of resource stocks, and rates of depletion coupled with discounting of the future”, Christensen (1987)). But his solution is to have a better understanding of the physical relation between the economy and the environment in order to extend “the range and content of prices (the market solution to environmental ‘externalities’)” (Christensen (1987)). But this pricing will not be sufficient to ensure “the long-term viability of the environmental-economic system” (Christensen (1989)): there will be a need for another regulation than market regulation alone (norm, law, quota, etc.).

That is why he needs a bio-physical approach to production. He starts from the Classical principle that value comes from production, and he adds to that “the low-entropy energy and materials extracted from the environmental systems and eventually returned as waste” (Christensen (1989))<sup>10</sup> and also the flows of information: following Boulding (1978), he claims that the three factors of production are materials, energy and know-how. Then the economy can be viewed as a set of chemical processes, or as an open thermodynamic system with solar energy as the sole input (as in Costanza (1980)). Inputs are complementary, as well as sectors of production: there is co-evolution between technologies as well as between the environment and the economy (Norgaard (1988)). On the same ground, time and geographic constraints should be reintroduced: production is a dynamic process, from extraction of natural resources to production of consumption goods, and each phase takes place and is influenced by a definite site. Novelty in techniques as well as change in demand should be introduced. Limits to growth can be traced back to the availability of natural resource and energy and to the availability of techniques of production.

About the pricing system, Christensen (2005) is close to the post-Keynesian theory of production<sup>11</sup>: in some post-Keynesian works (Kaldor (1979)), a dis-

<sup>10</sup>He does not explain if it is after or before extraction that natural resources should be taken into account.

<sup>11</sup>Post-Keynesian theory are mainly interested in growth dynamics, asking the question: “How does growth come about in a capitalist economy?” (Kronenberg (2010)). Their empirical penchant leads Post-Keynesian economics to reject the neoclassical explanation of production and distribution (rejection of aggregate production functions and general equilibrium theory), but they have never really been interested into environmental questions (part of the reasons are explained in Mearman (2005)). Nevertheless, there have been some attempts to connect ecological economics and post-Keynesian economics as they seem to be complementary approaches (see Kronenberg (2010)).

inction is made on the pricing of raw materials, subject to the law of supply and demand, and the pricing of industry goods, subject to price-cost pricing (or full-cost pricing, or again mark-up pricing). Christensen agrees with this and argues that extractive industries are more subject to differential rents because of different qualities of natural resources than manufacturing industries. Then there is a high variability of production cost in extractive industries (including agriculture): when demand is low, only the more profitable sites are used, when the demand is high, even bad sites are put into production<sup>12</sup>. He then explains that there is a connection between price of primary commodities and growth, as shown by the work of Hamilton with oil, for example (Hamilton (1983)).<sup>13</sup>

#### 1.1.4 JUDSON

Judson (1989) explicitly calls for a rapprochement between Sraffian and ecological economists, because they share the same theory of value. For him a theory of value must specify:

1. the scale of the analysis: micro in the case of utility value, macro in the case of labor-value. For Judson, the two scales and the two systems of value can co-exist: “if one can sum all of the inputs into a commodity, its value can be determined independent of subjective preferences. This value operates as a ‘center of gravity’ for a commodity’s price, around which its price will oscillate due to short term conditions” (Judson (1989)).<sup>14</sup>
2. the objectivity of the analysis: subjective in the case of utility value, depending on individual preferences, where labor-value is said to be “independent of exchangers’ preferences”, and thus more objective.<sup>15</sup>
3. the role of time into the analysis: marginal analysis, using utility value, is usually static (demand and quantities are initially given) where labor value is said to allow a dynamic analysis (proportional dynamics for instance).

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<sup>12</sup>But then he actually justifies the instability of raw material prices by the instability of the demand: then mark-up pricing could be used everywhere. I think it is more because of political and financial reasons that we can say that price of raw materials are not subject to markup pricing.

<sup>13</sup>And current neoclassical models can not explain why elasticity between oil and growth is so high :elasticity found in these models is around 10%, but in reality it is more around 60% (see Giraud (2014) on this point).

<sup>14</sup>He thus see the Sraffian analysis as an equilibrium theory, following Garegnani (1976) rather than Sinha (2012).

<sup>15</sup>On that point Judson says that labor value is the inherent value of a commodity: “if values inheres in objects in some operating way, then the ability of actors to modify the valuing structure is more limited”. I do not agree with Judson here, as I think that exchange value, even reduced to labor-value, is a value attached to a commodity by the specific system of production used to produce this commodity. Labor value is no more inherent than utility value, the first is attached by the system of production, the second by an individual.



Judson adds : “neo-Ricardian’s began to challenge the Marxian analysis, arguing that labor (the Marxian basis for commodity value) is only one of the many inputs into the production of commodities” (Judson (1989))<sup>16</sup>. On the same footing, Judson challenges the energy theory of Costanza: “Sraffa’s commodities are valued interchangeably with one another, while Costanza ‘carries back’ the costs into their energy value” (Judson (1989)). Here he seems to confuse the possibility to those who is appropriating the surplus and the notion of origin of value. It is true that all commodities can appropriate a part of the surplus (actually the owners of the commodities are appropriating it). But by saying this, we just say that there is battle for the surplus, we do not say “the origin of value can be track back to each commodities”. If we are in a pure labor economy ( $w = 1, \pi = 0$ ), we see that labor appropriates all the surplus, if we are in a pure capitalist economy ( $w = 0, \pi = 1$ ), we see that capital absorbs all the surplus. But nothing is said about the origin of value. If we say that the origin of value is labor, then we are able to see the level of exploitation of different systems (defining exploitation by the amount of labor value which is not given back to the workers).

Judson divides the energy theory of value into three schools (Judson (1989))

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- Energy-value of a commodity as the energy that the commodity can supply (the work of H.T. Odum is a good example, Odum and Odum (1981)). This vision is criticized by Georgescu-Roegen essentially because energy cannot substitutes matter (Georgescu-Roegen (1979)).
- Energy-value as the production cost of the commodity in terms of energy (Costanza (1980); Costanza and Neill (1981); Costanza and Hannon (1989)). This vision has been criticized by Daly (Daly (1982)) on the ground that the goal of the economy is not to maximize energy value, but utility value for consumers.
- Energy-value as an efficiency criteria to value ecosystems (Costanza and Neill (1984)): in this view, the goal of the ecological production is to produce the maximal surplus from an initially given amount of energy.

Instead of choosing one theory of value, Judson compares 2 systems of value: labor theory of value and energy theory of value, with energy as a cost of production (Judson (1989)). Elaborating on the work of Kregel (Kregel (1973)), he represents an economy with labor as the only means of production:

$$\mathbf{p}\mathbf{q}_c = D = \mathbf{w}(\mathbf{n}_c + \mathbf{n}_i) \tag{1.22}$$

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<sup>16</sup>Again I do not agree with Judson: the neo-Ricardian theory does not contradict the fact that in a capitalist system of production, labor is the substance of the exchange value, as it is always possible to reduce “prices of every commodities into a sum of profit weighted quantities of labour” (Pasinetti (1973)), even in case of joint production. This is because labor is the sole non-produced input in Sraffa’s system. This is justified on the economic point of view: the only non-produced inputs are the agents of production, who earn the surplus as revenue.

With  $\mathbf{p}$  the line vector of consumption goods prices,  $\mathbf{q}_c$  the column vector of consumption goods physical quantities,  $D$  the scalar of the demand for consumption goods, expressed in value,  $\mathbf{w}$  the line vector with in each element the uniform wage  $w$ ,  $\mathbf{n}_c$  the column vector of labor quantities required in each sector to produce the consumption goods and  $\mathbf{n}_i$  the same vector but for investment goods.

If there is no investment, equation 1.22 becomes:

$$\mathbf{p}\mathbf{q}_c = \mathbf{w}\mathbf{n}_c \quad (1.23)$$

Then, to produce the same physical quantity of consumption goods, Judson introduces a need for energy:

$$\mathbf{e}\mathbf{q}_c = \mathbf{e}_\epsilon\epsilon + \mathbf{e}_\tau\tau \quad (1.24)$$

With  $\mathbf{e}$  the line vector of the energy cost of production for each consumption good,  $\epsilon$  the column vector of the physical quantities of raw materials needed to be extracted,  $\tau$  the column vector of the physical quantities of raw materials needed to be transformed into consumption goods and  $\mathbf{e}_\epsilon$  and  $\mathbf{e}_\tau$  the line vectors respectively of the energy needed to extract one unit of raw materials and of the energy needed to transform one unit of raw materials.

If labor is the only means of production and if there is no investment needed, equation 1.24 becomes:

$$\mathbf{e}\mathbf{q}_c = \mathbf{e}_i\mathbf{n}_c \quad (1.25)$$

With  $\mathbf{e}_i$  the input of energy needed per unit of labor, each element being equal to  $e_i$ . Thus prices and energy prices becomes proportional:

$$\mathbf{p} = \frac{w}{e_i}\mathbf{e} \quad (1.26)$$

For Judson, this proportionality changes as soon as investment goods, produced by labor, are reintroduced. This is because the sale of the consumption goods must be enough to cover the costs of both the production of consumption and the production of investment goods. The energy cost of production is not changed, but the cost of profit - needed to invest - must be added to the price equation. The new system is thus written as:

$$\begin{aligned} \mathbf{e}\mathbf{q}_c &= \mathbf{e}_i\mathbf{n}_c \\ \mathbf{p}\mathbf{q}_c &= \mathbf{w}(\mathbf{n}_c + \mathbf{n}_i) \end{aligned} \quad (1.27)$$

Then equation 1.26 becomes:

$$\mathbf{p} = \frac{\mathbf{w}(\mathbf{n}_c + \mathbf{n}_i)}{\mathbf{e}_i\mathbf{n}_c}\mathbf{e} \quad (1.28)$$

Thus the “energy buying power of money” has decreased, because of the need for investments; prices have raised, but energy consumed is the same<sup>17</sup>.

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<sup>17</sup>We could of course wonder why energy is not needed to produce investment goods.

Judson stops here his analysis and ends by proposing new fields of research for ecological economists as well as neo-Ricardians:

1. Following the work of Costanza (Costanza (1980)), investigation of the relation between energy cost and price, through Input-Output analysis, on the world or national level;
2. Study of the differences between energy qualities and their impacts on the energy theory of value;
3. Dynamic analysis of past and futures energy values;
4. Comparison of energy values in different countries;
5. Study of international exchanges under the light of the energy theory of value.

So Judson does not go as far as Costanza, who reduces energy prices into monetary prices. Nevertheless, he ends his analysis by looking at the question of the energy buying power of money, and this can lead to the problem of introducing a money value on nature.

#### 1.1.5 Ecological prices: HANNON

Hannon tries an original exercise: to define the valuation by nature of human activities. But the result is a bit disappointing: he computes ecological prices, in a way very similar to Costanza (Costanza (1980); Costanza and Neill (1981)). He wants to construct an evaluation process independent on human decision, as “a useful compromise between the ecological purist, the intrinsic valuator and the neoclassical economist” (Hannon (1998)). Then he tries to take the point of view of the nature, and assumes that “nature acts as though it is trying to maximize [its] net output” (Hannon recognizes that this assumption is “an obvious appeal for a sort of natural Aristotelian final cause”). Thus in this way, if an activity destroys natural resources, its product is valued less than the product of an activity increasing nature net output.

He tries to justify this objective function of nature by saying that “even inanimate objects can be viewed as acting as though they have a purpose” (Hannon (1998))<sup>18</sup>. So for Hannon it should be possible to deduce from the observation of natural processes an “ecological ‘welfare function’”, making the parallel with the neoclassical attempt to build a “Social Welfare function” by looking at “the utilities of all the actors in an economic system”. But this parallel stops here, because Hannon adopts a macroeconomic point of view, looking at processes at a global scale, where neoclassical economists adopt an individualistic point of view. He finally justifies this “motivational assumption” by saying that if the goal of nature is to maximize its net output, then “the

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<sup>18</sup>This is true, but a purpose tries to answer a necessity, where a law can just be the result of blind chance.

less the natural system deviates from such a path, the more stable it is, and the more we can depend on it” Hannon (1998). Thus for him nature should operate as an efficient process, as it serves human purposes.

As the net input of nature’s system, he chooses “photosynthesized sunlight”: this choice is made under the assumption that “it is the limiting input in the production of the net output. Otherwise, the net input would be set in terms of whatever the limiting input happens to be”. A good question of course is: what if there are several limiting outputs? Then,

“an economist would say they are differently priced factors of production. To group them into a single vector of net inputs requires the idea of relative value of the different net input forms. By asserting a production function for the system, one could find the marginal productivities of each of the inputs and sunlight. It is easy enough to show that the value ratios are the ratios of the marginal productivities” (Hannon (1998))<sup>19</sup>.

For the sake of simplicity, heat and water inputs, which are other possible limiting inputs, are assumed to be of zero value.

The value of the net input is equal to the value added, i.e. the value of the net output of the system (unless we are in an open and dissipative system where the value of the output is less than the value of the input). Making reference to Samuelson (1966), he says that the only possibility to calculate positive prices from a system of process exchanges is when there is only one exogenous input (i.e. an input not produced by the system), single production and constant returns to scale (this last point is wrong, as Sraffa proves it, but never Samuelson (Sinha (2007)) nor Solow (Solow (2014)) understood this). Then the ecological price system is:

$$\mathbf{E} + \mathbf{eA} = \mathbf{eB} \tag{1.29}$$

Thus we obtain the same system than Costanza (Costanza (1980); Costanza and Neill (1981)). By adding human processes, Hannon expects to see whether the net output increases or decreases, thereby defining the value added of the human activity.

The goal behind this exercise is clear: “to elaborate a procedure that may be used to answer the natural system evaluation questions” and to raise a debate about how we “see ourselves as belonging to the living system, belonging to nature” Hannon (1998). This is an interesting point of view, because if we are a part of nature, then the procedure of valuation devised by Hannon is useless; and if we are not inside nature, how to differentiate natural processes to human processes? How to differentiate nature from artifice? Is there a difference (see the skepticism on that point from Clément Rosset Rosset (1973))?

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<sup>19</sup> This last sentence is not all “easy enough” to accept, because this depends a lot on the production function, and if all net inputs are limiting factors (or complementary inputs), a little increase of one input may not increase production

### 1.1.6 Neoclassical theory of value and ecological economics

A paper by Farber, Costanza and Wilson try to connect ecological economics and the neoclassical theory, by looking at the question of the valuation of environmental resources and services (Farber et al. (2002)). For them,

“‘value systems’ refer to intrapsychic constellations of norms and precepts that guide human judgment and action. They refer to the normative and moral frameworks people use to assign importance and necessity to their beliefs and actions” (Farber et al. (2002)).

So they have an individualistic starting point, looking at creation of value in someone’s mind, and not at the social level. Following that, they define value as “the contribution of an action or object to user-specified goals, objectives or conditions” (Farber et al. (2002)). So value is for them “use-value”, as it is attached to an object via a specific user. “Valuation” is defined as “the process of expressing a value for a particular action or object ... Ecosystem valuation represents the process of expressing a value for ecosystem goods or services (i.e. biodiversity, flood protection, recreational opportunity)”. As value is use-value, the valuation of an object is the act of giving a use-value to it, thus defining the object, the user, and the relation between both.

Then they try to distinguish between intrinsic and instrumental value. Intrinsic value arises when someone wants to sustain or protect an object, just because it deserves to exist, i.e. “irrespective of human satisfaction”. If we believe that some ecosystem or species, for instance, deserve the right to exist, apart from any human consideration, then we can deduce from this assumption the value of all other objects: “the value of any action or object is measured by its contribution to maintaining the health and integrity of an ecosystem or species, per se, irrespective of human satisfaction” (Farber et al. (2002)). These are intrinsic values, as the ones Costanza and Hannon tried to calculate in several papers (Costanza and Neill (1984); Hannon (1998)). So for each object, one could attached a right to exist, and then define the intrinsic values of all object, by relating them to the goal: “we must preserve the object”. Then one object can have multiple intrinsic values. A problem arise thus when two object deserves the right to exist, but cannot exist at the same time. Thus intrinsic values in both cases will be contradictory: how to chose between intrinsic values then?<sup>20</sup> These values are still given in relation to human choice (what deserves the right to exist), so in a way I would still call it “use-value”, even if the goal of this value is precisely to stop using or destroying the object. If no one believe that there is a right to exist for that object, then a set of intrinsic values disappears. And the problem of social choice (how to choose

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<sup>20</sup>In Costanza and Hannon Costanza (1980); Costanza and Neill (1981); Hannon (1998), the nature has a right to exist, but not individual ecosystems: they could be substituted, as, in these papers, the objective of nature is to maximize its net output, not to protect each ecosystem individually.

between different use-value?<sup>21</sup>) appears again when some rights to exist are contradictory: how to choose between different rights to exist?

Then on the other side there is what Farber, Costanza and Wilson call instrumental value: “instrumental values reflect the difference that something makes to satisfaction of human preferences. Instrumental values, such as economic values, are fundamentally anthropocentric in nature.” This is very close to the definition of “value” that they gave at the beginning: the only difference is that the user is now precisely defined as human. Again for me this is a definition of use-value. But for them, one example of instrumental values is economic values; so the economic value of one object is for them its contribution to user satisfaction. So they do not see any difference between exchange value (or economic value) and use-value, or more precisely they think that exchange value can be calculated just looking at the use-values<sup>22</sup>. They recognizes that “some needs may not be reducible to money or time”, but they overall agree on the way neoclassical theory attributes economic values to all objects, i.e. that “the marginal utility of the goods ... can be used to explain their exchange value” and that “time or money can ... be used as a standard of measure of use value” (Farber et al. (2002)). If there is no price on an object, a contingent valuation can be made by asking people what they would offer to protect the object (Willingness to Pay) or what they would receive to accept the destruction of the object (Willingness to Accept). And in order to go beyond personal utility, such contingent valuation could be made in a deliberative form between several people: this may help to construct a social value, and thus solve the social choice problem.

Finally they talk about another kind of value: ecological value. This value is different from use-value because “one cannot talk about ‘value’ as the degree to which an item contributes to achieving a goal in this context since there is no conscious goal being pursued” (Farber et al. (2002)). Ecological value actually could refer to two different relations<sup>23</sup>:

1. Ecological value could mean “the degree to which an item contributes to an objective or condition in a system ... For example, one could talk about the value of particular tree species in controlling soil erosion in a high slope area” Farber et al. (2002). An other definition can arise in

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<sup>21</sup>As Sonnenschein and Debreu shows (Sonnenschein (1973); Debreu (1974)), the form of the social demand function, aggregating all individual demands, can not be known in advance. Thus “à la question posée aussi bien par Samuelson que par Arrow et Hahn : est-ce que la recherche par chacun de son intérêt propre se traduit par le chaos ou l’harmonie, le théorème de Sonnenschein-Mantel-Debreu conduit à répondre, de façon inattendue : plutôt au chaos” (Guerrien (1992)). And this destroys the neoclassical theory of value, as Sonnenschein and Debreu shows that the relation of scarcity and value is not always positive (Guerrien (1992)).

<sup>22</sup>By overlooking this distinction, there is an implicit justification of the economic process of accumulation of exchange value. Economic growth is justified in the sense that, as it provides more exchange value, it provides more use-value. Then capitalism is justified, as a process that attributes exchange value to an object, and as a process that accumulates exchange-value.

<sup>23</sup>The same distinction appears in Winkler (2006) between the “economic-ecological analogy” and the “energy theory of value”.

the context of natural selection, when “one species is ‘valuable’ to the survival of another species. Extending this logic to the co-evolution of humans and other species, we can talk of the ‘value’ of natural ecosystems and their components in terms of their contribution to human survival”. Here we find again the definition of intrinsic value.

2. Ecological value could also mean energy-value (Costanza (1980); Costanza and Neill (1981); Costanza and Hannon (1989)). The goal of the energy theory of value is, for them, to “explain exchange values”, i.e. monetary or economic values. They think that exchange values could be explain if it is possible to find the “‘primary’ input to the production process”<sup>24</sup>, but “neither labor nor any other single commodity was really ‘primary’”. So labor cannot explain exchange values<sup>25</sup>. The energy theory of value postulates “that, at least at the global scale, free or available energy from the sun (plus past solar energy stored as fossil fuels and residual heat from the earth’s core) are the only ‘primary’ inputs to the system” Farber et al. (2002). Thus energy is the primary input of the production system and it can explain exchange values: “it appears that the empirical link between available energy and economic value is rather strong”.

But if the energy theory can explain exchange values, why can not labor do the same, as labor could be reduced to an average amount of energy? And furthermore is it possible that, at the same time, the marginal utility and the energy cost of production explain the exchange value of the same good, knowing that “Sraffa’s model of reproduction prices – the basis of energy-value analysis in practice – is to demolish the neoclassical demand and supply approach to value based on marginal utilities and marginal products” (Burkett (2006), p. 41)?<sup>26</sup>

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<sup>24</sup>About this primary input, they are referring to the principles of the production-based theory developed by Samuelson Samuelson (1966): for him, there only a possibility to calculate positive prices from a system of process exchanges if there is only one exogenous input (i.e. an input not produced by the system), if there is only single production and if there is constant return to scale. The last point have been proved wrong by Sraffa. The first point is true, but it must be understood in a mathematical sense, not in the physical sense.

<sup>25</sup>They also assert that the classical problem of Smith and Ricardo about finding the invariant measure of value can be reduced to the problem of finding the real primary input to the production process. They acknowledge that the classical problem was solved by Sraffa with his standard commodity of value, but they say that “the exchange values would not be independent of demand as Sraffa claimed” and that “Sraffa’s [mathematical proof] did not constitute a price theory in the sense of establishing the process of price determination” (Farber et al. (2002)). The first point is wrong, as Sraffa never claims that his prices where independent from demand (he calculates prices at one period of time, without any change in demand, but he never said that a change of demand will not change the set of price); and about the second point, it is true that Sraffa’s theory helps to calculate the price of production but does not explains how people put prices in the cornershop. Nevertheless I do not see why this would be a reason to reject the first step (see also Sinha (2012)). Anyhow, the energy theory of value does not solve those both points.

<sup>26</sup>Winkler (2006) actually tries to bring closer both approaches, but the result is yet another neoclassical model of production. In his model, the “world comprises a simple ecosystem, consisting of wilderness and bison and the interdependence between them. But in

### 1.1.7 STAHEL

On this debate around value, Stahel (2005) goes on the opposite line of Farber, Costanza and Wilson (Farber et al. (2002)). For him use-value is the source of wealth, but is definitely different from exchange value: “increased (re)production of exchange-values does not necessarily mean an equal increase in human wealth (in many cases even the inverse correlation holds)” (Stahel (2005)). He agrees with the definition from Smith of use-value, i.e. “the utility of a particular object” (Smith (1776), cited in Stahel (2005))<sup>27</sup> and for him, exchange-value is defined as market-price.

The point of his contribution is twofold. First he wants to demonstrate that both use and exchange values express an “emergent, context dependent relational property”. Concerning use-value, this is clear as:

“use-value is realized only in the relational act of consumption, as a subset of all different potential utilities of a given good or service, this process is clearly context dependent: it will depend on the material (or informational) content of the particular commodity, but also on the environmental, socio-cultural and individual (subjective) context in which it is consumed” (Stahel (2005)).

Regarding exchange-value, this have been demonstrated by Sraffa:

“different subsistence levels (seen as historically determined and thus varying over time according to the relative political force of the different classes) ... lead to different distributions of the product between wages, benefits and rent. These different levels thus lead to different relative exchange values of the commodities depending on the degree of labour-intensiveness of their production. In fact, this variability of the relative exchange-value of different commodities was the basis of Sraffa’s still unanswered critique of the very notion of neoclassical capital” (Stahel (2005)).

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addition the model also incorporates a simple economy, where humankind can assign labor between” producing food through farming or hunting bisons. After that, he assumes that society “agrees on a value system”. This system will attributes values to commodities “ex ante to guide further actions”: it is then clearly a system allocating use-values, in a anthropogenic way (not necessarily anthropocentric as protecting nature could be one goal of the society). In effect, that means choosing an objective function for the society (e.g. maximizing wellbeing depending on consumption and the environment left) and linking it with environmental and ethical constraints. He looks then at the sustainable paths for the economy and the environment. Thus he is actually dealing with a neoclassical model with intertemporal allocation of initial stocks. Distribution depends on the productivity of the factors of production, and he can deduce shadow prices of the environment by determining the amount of wellbeing the environment can offer. He can also deduce shadow prices of constraints by looking at “cost” of wellbeing the society is willing to sacrifice in order to respect the constraints (present and future cost, as this is an intertemporal analysis). But unfortunately this has nothing to do with a Sraffian analysis of exchange values and distribution.

<sup>27</sup>It is thus the same definition that Farber et al. (2002) use for “value”,



The second point of his contribution is to call for an approach of the economy as a complex, ever-changing object of study, very much in the line with Spangenberg (2005)<sup>28</sup>: “This non-linearity, scale and context dependency of any value is particularly true for what Funtowicz and Ravetz called emergent complex systems, which, as we saw, is the case of the human economic system” (Funtowicz and Ravetz (1994b); Stahel (2005)). Thus there is no possibility of “perfect foresight and complete control” (see also O’Connor (1994b) on that point) and no possibility of finding sustainable prices within the free-market regulation process as “no single perspective from within a subsystem of fewer dimensions can fully encompass the reality of the whole system” (Funtowicz and Ravetz (1994a)).

Then Stahel compares the economic process with the dissipative structures described by Prigogine (Prigogine (1972)): for him social and ecological wealth creation, i.e. use-value creation, is similar to the creation of far from equilibrium negentropy into dissipative structures. This kind of structures creates order from chaos and, for Stahel,

“as an extension of the process of cosmological and biological evolution, the driving force of any economic process (although not necessarily its outcome) is to generate ordered, low entropy structures such as houses, bread and computers ... If we take a long-term, cosmological perspective, ... the general evolution of our universe

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<sup>28</sup>On the evaluation debate, Spangenberg defines three different positions (Spangenberg (2005)):

1. Partisans of strong comparability and commensurability of all objects: they think that there exists “a common unit of measurement of the different consequences of an action based on an ordinal scale, like monetary value”;
2. Partisans of strong comparability and weak commensurability: they think that there exists “a common measure based on an ordinal scale of measurement”, i.e. that we can find “the existence of a single comparative term like ‘utility’ by which all different actions can be ranked”.
3. Partisans of weak comparability: they acknowledge that sometimes no common measure can be found between objects but they believe that in such situation, “irreducible value conflicts are unavoidable but compatible with rational choice, employing practical judgment”.

For Spangenberg weak comparability should be a basic concept for ecological economics, because “as far as we know there is no common factor, decisive for social cohesion, human satisfaction and the integrity of ecosystems” (Spangenberg (2005)). Thus ecological economics should stand against the neoclassical theory, which is based on the assumption that there are strong comparability and commensurability of all objects. Nevertheless, he thinks that this latter theory can give some insights about the sustainability of the economy through the capital stock approach, i.e. the calculation of total wealth indexes.

He argues that the economic system is a complex one, as “the behaviour of individual actors cannot be aggregated into a macro figure either mechanically or statistically, and as the patterns of exchange between actors are variable and evolve as well”. Thus prediction cannot be done, and in particular there should be no assumption on long-term equilibrium. This point was, for Spangenberg, demonstrated by Sraffa: “regarding ... the development towards equilibrium, Sraffa could show nearly 80 years ago that the assumed decline of marginal cost and utility leading to equilibria is the exemption rather than the rule”.

as a whole and of our biosphere in particular, seems to be characterized by an increasing complexity and diversity of life-forms”<sup>29</sup> (Stahel (2005)).

Finally Stahel draws a relation between this analogy and the post-normal value theory that he wants to develop, following Funtowicz and Ravetz (Funtowicz and Ravetz (1994b)). The post-normal theory of value helps to take decisions in front of complex problems (such as: is this project sustainable or not?); it starts from the recognition that “there are different competing and equally legitimate perspectives in each evaluation procedure” and that the (capitalist) economic one is just one of them. Then,

“the role of expertise and traditional evaluation procedures ... is to provide not only quantitative, but qualitatively sensitive information input for decision making. At the same time, it has to recognize its own limitations: ... it cannot give us the whole picture. Moreover, these inputs will be considered within the communications and political framework [in a self conscious way]” (Stahel (2005)).

And in order to adopt rational decisions in situations including “risk, uncertainty and different legitimate perspectives”, “the inclusion of the extended peer communities becomes a methodological as well as an ethical need” (Stahel (2005)).

### 1.1.8 PATTERSON

Patterson defines ecological prices as “the weighting factors inferred from models which describes energy and mass flows through ecological and economic systems” (Patterson (2002)). They represent also “ratios that measure the ‘value’ of an ecological commodity - e.g. solar energy per kilogram of apples” (Patterson (2002)). But what is “value”? Patterson talks about value “in terms of the biophysical inter-dependencies in the system” (Patterson (2002)). This is why the value measured by ecological prices is different from the value measured by the market, which is “based on consumer preferences and other factors that determine the exchange value in markets” (Patterson (2002)).

Ecological prices thus measure “*biophysical interdependencies* (or contributory values) implicit in the global ecological system and its economic subsystem” (Patterson (2002)). The goal is to highlights some processes or some resources which are important for the reproduction of the system, while there importance is not reckoned by usual price system. For instance,

“it is unlikely that the value of protozoa in the ecosystem would be measured in a [Willingness-To-Pay] survey, whereas in ecological

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<sup>29</sup>On that point I would be very prudent before asserting that evolution follows a path leading to continuously ever-increasing complexity (how much impressively complex species have disappeared? Are we that complex?)The same kind of “trend to complexity” can be found in the work of Passet (2010): again, I am very doubtful in front of such assertion.

pricing, the value of protozoa in the ecosystem would be taken account of by the ... linkages they have with other components of the system” (Patterson (2002)).

Thus this approach is seen as “a complementary approach” to neoclassic valuation, and could be used “as a component of a multicriteria framework” (Patterson (2002)).

How does it works? Patterson writes down the equations representing exchanges between ecological and economic processes. In order to have prices which “make ecological sense” (Patterson (2002)), the processes must:

- obey to the First Law of Thermodynamics, i.e. mass and energy inputs must equal mass and energy outputs for all processes;
- refer to the Second law of Thermodynamics, i.e. “a degradation of the (thermodynamic) value of energy and materials” (Patterson (2002)) must appear;
- be open, because ecological and economic systems are open systems;
- have “multiple inputs and outputs (joint products)” (Patterson (2002));
- be interdependent<sup>30</sup>;
- be part of a dynamic system, i.e. be subject to change in the course of time: “ecological system will most likely not be at equilibrium” and “economic systems at any point of time are most likely not to be at equilibrium” (Patterson (2002)).

Then, in order to calculate ecological prices, Patterson develops the following model:

$$\mathbf{A}\mathbf{p} + \mathbf{e} = \mathbf{B}\mathbf{p} \tag{1.30}$$

With  $\mathbf{A}$  and  $\mathbf{B}$  the matrices of input and output coefficients,  $\mathbf{p}$  the column vector of prices, and  $\mathbf{e}$  the vector of “residuals”. These residuals appear when there is two or more processes producing the same commodities, but with a different efficiency. A regression method is thus used to find the “average” process, such as constrained least square method. Recently he has developed “an Eigenvalue-Eigenvector” method to find these average prices (Patterson (2002); Patterson et al. (2006)). The goal is to find the minimum eigenvalue  $\lambda_{min}$  that satisfy the price equation:

$$[\mathbf{B} - \mathbf{A}]^t [\mathbf{B} - \mathbf{A}] \mathbf{p} = \lambda_{min} \mathbf{p} \tag{1.31}$$

Patterson relates his approach of ecological prices with:

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<sup>30</sup>Patterson do not define interdependence in a mathematical way, and makes no observation about the difference between basic and non-basic goods or processes.

- the method developed by Odum (1996) to calculate transformities: “the only difference is that transformities only focus on energy transformation, whereas ecological pricing focuses on both energy and mass transformation” (Patterson et al. (2006)). Patterson rejects the view that ecological prices should be expressed in energy equivalent, because solar energy is not the only input to the system (geothermal, uranium and fossil energy can also be listed) and because he is dubious about the “maximum power principle” (Odum (1996)) which stands that ecological systems tends to favour the more energy efficient processes: “it is doubtful whether an ecological-economic system does (or for that matter should) operate according to just one objective function” Patterson (2002). For him whatever numeraire can makes the point, as relative prices will not change: “indeed, the Economic Output quantity (\$ value added) can be used as the numeraire if so desired - this may be imperative in terms of ‘communicating’ the result of any ecological pricing exercise” Patterson (2002).
- the method developed by Sraffa Sraffa (1960). For him, Sraffa’s model is “an equilibrium model generating equilibrium prices, as the equation structures only permits equal ‘interest’ rates (efficiencies) for each process” Patterson et al. (2006) and Sraffa’s method is violating thermodynamics laws, because all exchanges are not taken into account (waste and natural extractions are ignored) and because there is no assumption of energy and mass balance (the surplus is created out of air) (Patterson (1998)). Nevertheless, Patterson thinks that Sraffa’s approach can become “the basis for objectively measuring the contributory value of species, in terms of how one species contributes to the value (livelihood) of other species” (Patterson et al. (2006))<sup>31</sup>.

In an attempt to compare Costanza’s famous study on the value of nature (Costanza et al. (1997)) with his method, Patterson finds that “the value if primary ecological inputs is \$24.73 trillion, compared with \$25.79 trillion for global GDP, giving a ration of 0.98” (Patterson (2002)), while Costanza found a ratio of 1.32<sup>32</sup>. An other founding is that “the ecological prices (with the exception of fossil fuels) show a good correspondence with actual market prices

<sup>31</sup>I think Patterson is wrong when he considers Sraffa’s theory: it is a non-equilibrium theory. The fact that there is an equal “efficiency” for all processes is because is introducing differential rent as the way to compensate for inequalities in the productivity of one factor of production. And the fact that he is not dealing with natural resources and waste is not because he thinks that value can be created with air, but that his only concerned is about interdependent systems of production, which only marketed commodities. Natural resources and waste are thus considered as non-relevant for his system of production, because they are not priced: there is no economic exchange with nature (to rephrase Perrings (1987), there is only exaction and insertion).

<sup>32</sup>In ecological pricing models, there is no profit on natural processes. Thus, if there is a surplus, the value of the surplus is “distributed” to the non-produced input: this is actually justified by the ecological pricing authors on the footing that the real value added comes from the sun, or from other primary inputs. But what they do not acknowledge is that this “distribution” means that the “owners” of the non-produced input are able to buy the

... The ecological price [of fossil fuels] is about seven times the market price” (Patterson (2002)), thus in accordance with other studies showing that fossil fuels prices are forced to stay low (because of political decisions) and that the elasticity of the GDP with fossil fuel is underestimated (Giraud (2014)).

### 1.1.9 SCIUBBA: extended energy accounting

Linking the field of ecological economics with the field of industrial ecology (Frosch and Gallopoulos (1989); Ayres (1989); Erkman (1998)), Sciubba (2005) wants to revive the energy theory of value. But as “all applications show that introducing second law considerations in the analysis leads to results that provide more precise and useful information for the design engineer, as well as for the energy planner” (Sciubba (2005)), he chooses exergy rather than energy as basis of his analysis.

Exergy can be defined as the embodied energy of a unit of matter or energy which is available to perform a physical work. In the definition used by Sciubba, the exergy of a unit of mass (or energy) at state 1, by comparison with a reference state 0, is the following:

$$e_1 = h_1 - h_0 - T_0 (s_1 - s_0) + \sum_i (\mu_i c_i - \mu_0 c_0) [kJ/kg] \quad (1.32)$$

With  $h_i$  the specific total enthalpy,  $T_0$  the temperature of the reference state,  $s_i$  the specific entropy,  $\mu_i$  the chemical potential and  $c_i$  the relative concentration. This definition favors an engineering point of view, as Sciubba chooses to “neglect other lesser contributions (molecular vibrations, nuclear, magnetic, etc.)” (Sciubba (2005)). The chosen reference state is the environment defined as “the portion of the universe that is outside of the boundaries of the modeled system” (Sciubba (2005)). As the quality of energy decreases after each round of production, the exergy of the outputs of an industrial process is always lesser than the exergy of its inputs.

The exergetic cost of a product is the sum of all exergetic inputs required directly and indirectly to produce it, divided by the product exergy (and the conversion efficiency of a product is the inverse of its exergetic cost):

$$c_i = \frac{\sum \mathbf{E}_{input}}{\mathbf{E}_{product}} \quad (1.33)$$

Sciubba’s goal is “the development of a formally complete costing theory based on exergy metrics”, because “exergy destruction ... represents the driving

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whole surplus: the total value of non-produced inputs becomes equal to the value of the surplus. Confirmation of this statement can be found in Patterson (2002), where Patterson finds that the net inputs (solar and geothermal energy, fossil fuels, uranium) have a total value of 0.98 times the value of the net output (global GDP): this is actually an imposed result of the analytical framework. And if this analytical framework is justified in a market analysis where companies needs to sell their production, it is hardly justified in ecological pricing, when there is no agents of production and no market.

force of all life forms” (Sciubba (2005)).<sup>33</sup> He performs the reduction of flows of matter and energy used in production into exergy values:

“A material stream is assigned a total (or cumulative) exergetic content defined as the sum of its raw state exergy and of all the net exergetic inputs received, directly or indirectly, in the extraction, preparation, transportation, pretreatment, and manufacturing processes” (Sciubba (2005)).

The problem of this reduction is that matter quality is no more taken into account: usually people do not choose a material over an other just looking at their relative exergies. Thus Sciubba defends himself by arguing that:

“extended exergy does not define a scale of practical or virtual preferences: it enables, though, a process engineer or an energy planner to exactly compute the resource-equivalent consumption embodied in the unit mass of two different artifacts ... Extended exergy is an indicator of resource consumption, not of individual or social preference” (Sciubba (2005)).

But for him economic value is nonetheless related with exergy: “it clearly appears that exergetic content, and not capital, is the correct measure for the worth of a commodity or a service, and that the monetary price ought to reflect this new measure of resource consumption”. So just looking at their relative exergies, one can know which material is more valuable, in an economic sense. But is the economic value not expressing individual or social choice? Sciubba’s answer is that “when making a choice in an economic sense, one is confronted with three different quantities: monetary value, use value (economic value to the purchaser), and intrinsic (resource-based) value” (Sciubba (2005)). Thus for him exergy can be used to reflect the intrinsic (exergy-based) value of a product, which should not be confounded with exchange value, the latter being synonym of use value and being usually measured with money: “anything can be money, from stones and metals to paper, and that what makes these things money is not what they are, but what they are used for. Furthermore, their value as money is separate from their intrinsic value” (Sciubba (2005), he follows an argument developed by Friedman (1992)).<sup>34</sup>

The originality of Sciubba’s proposal lies in the reduction of capital, labor and environmental remediation expenditures into exergy flows. To know the

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<sup>33</sup>Here again there is a confusion about the mandatory conditions for production and the source of exchange value, as Sciubba states that there exists an “intrinsic and direct correlation between exergy and economic value”. Economic or exchanged value, expressed by money prices, is a result of a capitalist way of producing commodities, not the expression of an intrinsic value correlated with exergy.

<sup>34</sup>I think Sciubba is wrong on two points: first an intrinsic value for a commodity does not exist, value is always relative. Second use value is not reflected by exchange or monetary value. Exergy is not correlated with use value, but can be correlated with exchange value, as the environment and more specifically the use of energy is a condition for the production of commodities. Finally exergy is indeed an “indicator of resource consumption”, but not really more than that.

extended exergy content of capital ( $ee_{cap}$ , equivalent for him to the extended exergy content of money), Sciubba multiplies the monetary cost of the capital with the extended exergy coefficient of capital ( $K_{cap}$ ). This latter coefficient is given by the global exergy input ( $\sum \mathbf{E}_{input}$ ) divided by the amount of global monetary circulation ( $M2$ ):

$$ee_{cap} = c_s K_{cap} = c_s \frac{\sum \mathbf{E}_{input}}{M2} \quad (1.34)$$

So if there is a creation of money while the input of exergy inside the economy stay constant, the extended exergy content of capital will go down. For Sciubba the choice of  $M2$  is “arbitrary”: we come back here to the question of building a bridge between two value systems. Two problems arise then: on one hand, money can be used to evaluate environmental services, and on the other hand exergy content can be different depending on the country we are looking at (thus it is not an intrinsic value anymore, it depends on social choice).

The reduction of labour into exergy is done by dividing the exergy input of one sector by the number of working hours in that sector:

$$ee_{lab} = n_{hours} K_{lab} = n_{hours} \frac{\sum \mathbf{E}_{input, Sector}}{n_{hours, Sector}} \quad (1.35)$$

This reduction is essential for Sciubba as “the attribution of a purely monetary value to labor is unsatisfactory because it assigns a higher weight to market conditions and financial considerations than to social, technical, and environmental issues” (Sciubba (2005)). Thus this reduction tries to mitigate this, in a politically neutral way, as “EEA is not a social or political theory” (Sciubba (2005)).

A little exercise may help to understand then the theory of value of Sciubba: let us look at one country, producing only one commodity, by the help of energy, money and capital.

$$\begin{array}{ccccccc} \textit{Exergy}_{input} & \textit{labor} & \textit{capital} & & \textit{Exergy}_{output} & & \\ \mathbf{E}_{input} & n_{hours} & M2 & \rightarrow & 1 & & \end{array} \quad (1.36)$$

We can calculate the exergy extended content of capital and labor flows:

$$ee_{cap} = M2.K_{cap} = M2 \frac{\mathbf{E}_{input}}{M2} = \mathbf{E}_{input} \quad (1.37)$$

$$ee_{lab} = n_{hours} K_{lab} = n_{hours} \frac{\mathbf{E}_{input}}{n_{hours}} = \mathbf{E}_{input} \quad (1.38)$$

Then the exergy cost of the commodity is equal to:

$$\frac{\mathbf{E}_{input} + ee_{lab} + ee_{cap}}{1} = \frac{\mathbf{E}_{input} + \mathbf{E}_{input} + \mathbf{E}_{input}}{1} = 3\mathbf{E}_{input} \quad (1.39)$$

So actually we can see that the theory of value of Sciubba is constructed in order to give an equal weight in the production of value to capital, labor, and energy. More precisely the value coming from the stream of capital equals the value coming from the stream of labor, and this value is equal to the value of the exergy input of the system (where in Costanza (Costanza (1980); Costanza and Neill (1981)) and Hannon (1998) for instance, the value of the energy input is the sole stream of value coming from outside the system). Even if Sciubba claims that EEA is not a political theory, his view of the origin of value is a political one, as a theory of distribution where energy, labor and capital are remunerated in the same way could be deduced from his theory.

Finally Sciubba adds to that the cost of environmental remediation: he is against the reduction of this cost into money through Willingness To Pay studies because:

“willingness to pay and the attitude toward a sustainable resource exploitation are different in different countries, and may well vary in time: therefore ... the method actually promotes an *unfair transfer, not only of the pollution, but also of the associated health risks from one region to another*” (Sciubba (2005)).

Indeed, “the poor sell cheap” principle (described by Martinez-Alier (1995)) tells us that the pollution cost of remediation may be lower in poor countries: thus these kind of studies will promote a displacement of polluting industries in such regions.

Thus Sciubba defines “the environmental pollution avoidance cost, calculated as the additional extended exergy expenditure that is required for bringing all environmental discharges down to a zero physical exergy level” (Sciubba (2005)). Sciubba’s goal, by doing this reduction, is to provide “a consistent basis for the calculation of the environmental externality” (Sciubba (2005)). This cost is to be added to the exergy inputs of the product in order to know his real cost. If we take again the previous example, the exergy cost of the commodity becomes:

$$\frac{\mathbf{E}_{input+ee_{lab}+ee_{cap}+\mathbf{E}_{rem}+ee_{lab,rem}+ee_{cap,rem}}}{\mathbf{E}_{input+rem}+\mathbf{E}_{input+rem}+\mathbf{E}_{input+rem}} = 3\mathbf{E}_{input+rem} \quad (1.40)$$



## 1.2 The second direction: try to express the power struggle

### 1.2.1 ENGLAND

England has been one of the first to specifically talk about the ecologization of Sraffa, and the link that could be drawn between Sraffa and ecological economics, in order to compete against the neoclassical theory (England (1986)).

He first describes how is depicted production in the neoclassical theory: first there is a distinction between inputs and factors of production<sup>35</sup>, then inputs are transformed into commodities. Thus there is no importance “attached to the historical processes whereby ‘factors of production’ have come into being” (England (1986)). Then he describes the neo-Ricardian theory: natural resources are said to be non produced and in short supply (so they can receive a rent), quantities of inputs (not different from factors of production) “can vary historically”. Production is divided between inputs for an other cycle of production and surplus, and then surplus is distributed among the population. In order to define the surplus, one must look at the physical requirements for the system of production to carry on, and more specifically at the natural resource requirements, such as land. He touches upon the problem of the definition of labor in this theory: is it a produced input, or non-produced input? I.e. is consumption a process included in the economy or not (see also Cogoy section 1.2.4 on this point)? England connect this point with the dichotomy between objective and subjective needs (see also Martins 1.2.9 on this point). For him, if labor is seen as an input, then part of the consumption becomes a requirement for the system, and then becomes an objective need. But the consumption process “is not governed by profit criteria” (England (1986)), and this may explain why Sraffa chose to represent labor as a non-produced input.

England then talks about the new (at that time) field of environmental economics, through two of its major contributions to the economic science: the importance of waste (they harm the environment, and thus harm both life quality and natural resource production) and the definition of natural services (or ecosystem services). For him environment and society should be seen as a whole, and not as two separate blocks; that is why he is considered as one of the fathers of ecological economics. He thinks that solution to environmental problems can be found by changing “the social organization of production” and not just through market regulations. This is the reason why he thinks that both environmental and neo-Ricardian schools should work together.

In order to initiate the movement, he develops a dynamic neo-Ricardian model, with one produced commodity, corn, and one jointly produced waste,

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<sup>35</sup>An input receives a price, a factor of production receives a revenue: distribution of revenue is determined after the price assessment, the latter occurring through the mechanism of offer and demand. The distribution of revenue does not impact the value of the surplus which is distributed. If there is a change in distribution, for instance through taxation, the demand will change and thus prices will change. In the Sraffian theory, distribution influences prices and prices and revenues are simultaneously determined.

emission. To produce one unit of corn and  $e$  units of emissions, there is a need for  $a$  units of corn, a quantity  $h$  of human labor,  $n_1$  units of land,  $n_2$  units of sunlight,  $n_3$  units of precipitation and  $n_4$  units of  $\text{CO}_2$ , with land, sunlight, precipitation and  $\text{CO}_2$  natural resources with no price and no rent. There are several technologies to produce corn, depending on coefficients  $e$ ,  $a$ ,  $h$ , and  $n_i$ . Technologies with lower  $e$  (production of emission) have higher  $a$  and  $h$  coefficients (inputs of corn and labor). Furthermore,  $\lim_{e \rightarrow \infty} a(e) = \infty$  and  $\lim_{e \rightarrow \infty} h(e) = \infty$ .

If there is no emission regulation, the chosen technology is written  $e_0$ ,  $a_0$ ,  $h_0$ . If there is a regulation, the lowest level of emission possible is attained when the corn input is equal to the corn output: this technology is written  $e_1$ ,  $a_1 = 1$ ,  $h_1$ . Then England writes down the price system, with wage paid in advance for the process of production:

$$p = p(1+r)[a(e) + wh(e)] \quad (1.41)$$

If the price of corn is the numeraire, the price system becomes:

$$1 = (1+r)[a(e) + wh(e)] \quad (1.42)$$

And we can find the relation between the wage and the rate of profit:

$$r = \frac{1}{a(e) + wh(e)} - 1 \quad (1.43)$$

Thus “the highest possible profit rate ... is realized when the real wage rate is zero and there is no environmental protection” (England (1986)). If the lowest emission is chosen, then the rate of profit and the wage becomes equal to zero, as production ceases. Between these two points, for each emission level, the surplus decreases and can be appropriated by wage earners or capitalists. For England,

“these results suggest that there is no single ‘socially optimal’ level of pollution. Rather, various social classes stand to gain the most from different and conflicting levels of environmental quality. The particular level of environmental quality actually enforced by the state will presumably reflect the relative political power of those various social classes and hence their respective capacities to influence government decisions on environmental protection” (England (1986)).

From that analysis, England thinks that the notion of class struggle must be enlarged to take into account environmental problems:

“In an earlier era of capitalist development, class conflict between workers and capitalists centered on such issues as the length of the working-day and the size of the bundle of wage goods customarily consumed by working-class households. Now, however,

there are attempts by workers not only to escape from physically and mentally debilitating work environments through a shortening of the working-day but also to impose techniques of production on capitalists which improve environmental quality in the workplace and in working-class communities. Those proletarian efforts need to be recognized and incorporated within modern political economy” (England (1986)).

This class struggle can then be seen as a fight between capitalists who want a higher profit, workers who want an higher wage and environmentalists who want a environmental protection. The question is then: who are these environmentalists? Are they workers or capitalists? Or neither of two options, living in non-capitalist society? Or maybe there is no need to define a class defending the environment, as the protection of the environment will emerge as a social need?<sup>36</sup>

## 1.2.2 PERRINGS: rents and externalities

### 1.2.2.1 The physical system

Perrings tries to consider the impact of externalities generated by the economy on the environment, through a joint production model. Externalities are first defined in this way: “the basis of external effects is the non-independence of the preference and production functions of economic agents who operate within a common environment, but who do not meet in the marketplace” (Perrings (1987), p. 1).

In order to take into account externalities, he wants to avoid the market solution prevailing in environmental economics, i.e. the introduction of taxes and subsidies or the definition of prices through subjective valuation. For him this kind of solutions leads to the attribution of rights - to pollute or to extract - on resources previously considered as common goods, and furthermore does not revolutionize the way we look at the economic system.

Indeed two strong hypothesis are always assumed in neoclassic theory: environmental goods have no price - “free gifts” - and wastes can be emitted in the environment without cost - “free disposal”. In ecological economics, for Perrings, both hypothesis should be rejected.

To prove that he constructs a world model based on 5 hypothesis (Perrings (1987), p. 18-21):

1. The system is thermodynamically closed (but not isolated), thus there is energy exchanges with the outside of the system (i.e. space) but no material exchange.

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<sup>36</sup>Actually what we see is that, even if in certain countries it effectively emerges as a political consensus that the environment should be protected, the tension between this protection and the desire for higher profits and higher wages stay high and visible, and the protection of the environment needs the action of activists to survive as a political choice.

2. The system is not decomposable, i.e. economic and environmental processes are interdependent.
3. It is possible to represent the system through joint production processes, with a number of processes equal to the number of resources, each process using at least one input, each resource being produced by at least one process. These resources include for Perrings goods produced by the economy (“commodities”) but also labor and natural resources: “what is unusual is the inclusion in the model of environmental resources: those that do not have the status of commodities. Such resources are not valorized - they lie outside the the price system of the economy” (Perrings (1987), p. 11).
4. Processes produce new resources, degraded means of production (equivalent to older fixed capital in Sraffa) and wastes (defined as the difference between the inputs and the two first kinds of outputs).
5. All technical coefficients are fixed, meaning that constant return is assumed, but technological changes are possible.

Perrings chooses to only consider material exchanges (Perrings (1987), p. 19). A technology is defined in this way:

“technology means the pool of knowledge that bounds all material transformations of the global system. It thus represents the sum of all the historically acquired chemical, genetic, intuitive, or recorded knowledge of material transformations” (Perrings (1987), p. 21).

Technology is represented by two matrices  $\mathbf{A}$  and  $\mathbf{B}$  with, respectively, inputs and outputs coefficients:

$$\mathbf{A}(t) = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (1.44)$$

$$\mathbf{B}(t) = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ b_{n1} & b_{n2} & \cdots & b_{nn} \end{bmatrix}$$

Both matrices are non-negative, and  $\mathbf{A}(t)$  is non-decomposable. The  $n$  rows represent the  $n$  processes, and the  $n$  columns, the  $n$  resources.

Let  $\mathbf{q}(t)$  be the line vector describing available mass in the beginning of each period of production. If the hypothesis about mass conservation (hypothesis 1) is retained, we can represent the constraint on the system in the following way, with  $\mathbf{e}$  the column vector unity and  $\mathbf{q}^t$  the transpose of vector  $\mathbf{q}$ :

$$\mathbf{q}(t) \mathbf{e} = \mathbf{q}(t+1) \mathbf{e} \quad (1.45)$$

$$\mathbf{A}(t) \mathbf{q}^t(t) = \mathbf{B}(t) \mathbf{q}^t(t) \quad (1.46)$$

If we define the rate of material growth of the system as:

$$g = \frac{\mathbf{q}(t+1) \mathbf{e}}{\mathbf{q}(t) \mathbf{e}} - 1 \quad (1.47)$$

Then the respect of hypothesis 1 leads to a rate of growth equal to zero. Thus, if hypothesis 2 is confirmed in reality, each time a model assumes a rate of growth superior to 1, there is a implicit assumption of free gift from nature.

Perrings then goes on the assumption of “free disposal” (Perrings (1987), p. 28-29). This hypothesis implies the following relationship:

$$\mathbf{q}^t(t) > \mathbf{A}(t) \mathbf{q}^t(t) \quad (1.48)$$

Thus some resources are non used as inputs by the system and disappears. If hypothesis 1 holds, this can only be true for a subsystem inside the global system. But at the global system level, we can only have:

$$\mathbf{q}^t(t) = \mathbf{A}(t) \mathbf{q}^t(t) \quad (1.49)$$

This latter equation means that if there is a technological change in one process, an other technological change is implied, in order to keep true the mass balance principle. This also implies that a system with a stable technology have to follow this relationship.

Then Perrings looks at some possibilities in order to relax hypothesis 2 (Perrings (1987), p. 31-33). System 1.44 would be decomposable into two subsystems if we could write it, through rows and columns permutation, as:

$$\mathbf{A}(t) = \begin{bmatrix} \mathbf{A}_{11} & \mathbf{A}_{12} \\ 0 & \mathbf{A}_{22} \end{bmatrix} \quad \mathbf{B}(t) = \begin{bmatrix} \mathbf{B}_{11} & \mathbf{B}_{12} \\ 0 & \mathbf{B}_{22} \end{bmatrix} \quad (1.50)$$

Perrings (Perrings (1987), p. 33) then explains that the system may be considered decomposable if processes are distant in time. Indeed a technological change in one process will little by little affect all processes if the system is non decomposable, but some processes will wait several periods before being affected. We can then consider the system as decomposable during a short period of time.

Then Perrings introduce the assumption that each process is owned by a specific class of agents. If two processes are interdependent, it means that they both need at least one output from the other process to operate. An exchange is needed and Perrings defines it as a transaction: “A transaction implies the real exchange of the outputs of distinct processes to mutual advantage and by the agreement of the agent involved” (Perrings (1987), p. 34).

But is there always mutual agreement? Let the system 1.44 be composed of only two process with the following technology:

$$\mathbf{A}(t) = \begin{bmatrix} a_{11} & a_{12} \\ 0 & a_{22} \end{bmatrix} \quad \mathbf{B}(t) = \begin{bmatrix} b_{11} & 0 \\ 0 & b_{22} \end{bmatrix} \quad (1.51)$$

In this kind of system, owners of process 1 do not produce anything that can be used in process 2. There is no need for owners of process 2 to give a part of their output to process 1: there is no mandatory transaction. Then Perrings introduces the terms “exaction” and “insertion” to describe the possible outcomes of such situation:

“an exaction implies the forcible uncompensated acquisition of the outputs of one process by the agent(s) operating another process. An insertion implies the forcible uncompensated imposition of the output of one process, by the agent(s) operating that process, on another process” (Perrings (1987), p. 35).

In system 1.51, there may be an exaction of resource 2 by the owners of process 1, or an insertion of resource 2 by the owners of process 1. This depends on power relationships between agents. An exaction can occur for instance when a process extract a non renewable resource and an insertion when there is waste disposal in the environment, without, in each situation, an agreement by the “owners of the environment”<sup>37</sup>.

Insertions and exactions are not fair, but they can be sustainable: for instance if the growth rate of process 2 is higher than the growth rate of process 1, the exaction can be sustainable. If it is not the case, resource 2 starts being depleted.

About technological stability, Perrings (Perrings (1987), p. 43) then inquires if a subsystem can at the same time conserve a stable technology while freely disposing waste in the environment. If hypothesis 2 is retained, then this can only be the case in a limited period of time, because all processes are connected. Perrings highlights here the difficulty of knowing both the distance between two processes (the time frame before one process is impacted by the change in an other process) and the technical relationship that exists between two processes. The global system can not be controlled, and even not observed (i.e. we can not understand all relationships).

This allows Perrings to criticize the neoclassical approach about environmental problems: this approach assumes that when a resource becomes *relatively* scarce, its *relative* price will increase and new techniques of extraction and recycling will emerge. It assumes as well that it is possible to evaluate the *relative* cost of a pollution - which increases only if the pollution *relatively* increases - and then to develop control policies allowing to obtain the socially optimal level of pollution. There is no account of the absolute scarcity of some resources - because neoclassical economists assume that prices will force substitution - and the possibility of non-control of environmental conditions - because they say that it is just a matter of an efficient allocation of resources. Thus for

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<sup>37</sup>This leads of course to the question: who are those owners?

the neoclassical economy there is no absolute limit of the economic subsystem, even if all economists agree that Earth is not infinite.

The only possibility for the system to keep growing, is to continuously find new resources to deplete, i.e. to continuously change the existing technology: the magic key is to keep introducing new resources into the economic subsystem. And then maybe the global system will become controllable, but when this goal will be achieved, growth will end. Because there is indeed some absolutely scarce resources, and because energy and matters are continuously degraded, and recycling can not be complete.

### 1.2.2.2 The value system

Perrings investigates how the relationship between the economy and the environment affects the creation of exchange values. He starts with the definition of exchange value: “the value of a resource is defined to be a corresponding transaction weight fixed by the conditions of production, distribution, and exchange” (Perrings (1987), p. 65). He is not considering use-value, but he points out that a resource will have a positive price only if it generates a positive marginal utility<sup>38</sup> (Perrings (1987), p. 65).

But if this latter condition is necessary to have a positive price, it is not sufficient, as it also depends on ownership: only owned commodities can have a price, and commodities are defined in this way:

“commodities in such a system imply resources that have value in exchange and are subject to well-defined rights of property. They include not only products in the usual sense of the word, but also labor and any valorized resource extracted from the environment” (Perrings (1987), p. 11).

Labor is thus a commodity, but natural resources are not: they have no price because they are not subject to rights of property - “they lie outside the the price system of the economy” (Perrings (1987), p. 11).

Then he sets up the definition of a value system inside an economy:

“the value system is defined to be the set of transaction weights governing the exchange of resources between the agents controlling the mutually dependent processes of a human economy. The value system is thus coextensive with the market” (Perrings (1987), p. 65).

Interdependence between economic processes ensures that the input matrix is non-decomposable, and thus that there is one unique solution for each price. Then he adds: “The value system is any system of weights establishing the ratio in which resources, defined in terms of property rights, are exchanged one for another” (Perrings (1987), p. 66). Thus again ownership rights on resources

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<sup>38</sup>This is rather strange: why at the margin? It seems sufficient to say that a good should generate utility if one wants to sold it with a positive price.

are the way to know if there will be a price (or not - exchange values can be set to zero) on a specific resource.

In order to define his price system, Perrings adds two hypotheses:

1. Prices depends on conditions of production and of distribution. The first means the technology of the system used, the latter the conditions governing the sharing of the surplus. In Perrings terms, these conditions of distribution include “the extra-economic - cultural, legal, ideological, and political - conditions affecting the distribution of income between the proprietors of distinct factors of production” (Perrings (1987), p. 67).
2. There is a high degree of complementarity between resources.

This latter hypothesis explains why conflicts in the distribution of the surplus can occur. By assuming that there is competition between the different owners of the means of production, PERRINGS comes close to MARX: the only possibility for owners of the same mean of production to increase their share of the net surplus is to join forces against the owners of the other means of production (because competition ensures that they will get the same rate of profit on their shared resource, Perrings (1987), p. 67-68). They will act like a *class*, in a Marxist sense: “the economic actors of interest are not individuals per se, but the group of proprietors of each set of perfectly substituable resources advanced in production” (Perrings (1987), p. 68). But the fact that he connects the origin of the struggle in the limited supply of resources tells us that the capitalist system of production (and distribution) is not actually contested (see Burkett, section 1.2.7).

His price system with joint production can be written like this (Perrings (1987), p. 71), without environmental resources (which bear no price) and environmental processes (which are not owned):

$$\mathbf{B}(t)\mathbf{p}(t+1) = \mathbf{A}(t) [\mathbf{I} + \mathbf{D}_{r_j}(t)] \mathbf{p}(t) \tag{1.52}$$

With  $\mathbf{B}$  and  $\mathbf{A}$  the matrices describing the technology, with, respectively, inputs and outputs coefficient for the  $n$  commodities (in columns) used in the  $n$  processes of production (in rows) during period of production  $T$ ,  $\mathbf{p}$  the column vector of prices, and  $\mathbf{D}_{r_j}$  the diagonal matrix having in its main diagonal the  $n$  absolute rents  $r_j$  for each commodity  $j$ .

We can then represent system 1.52 under the following form:

$$\begin{bmatrix} b_{1,1} & \dots & b_{1,n} \\ \vdots & \ddots & \vdots \\ b_{n,1} & \dots & b_{n,n} \end{bmatrix} (t) \begin{bmatrix} p_1 \\ \vdots \\ p_n \end{bmatrix} (t+1) = \begin{bmatrix} a_{1,1} & \dots & a_{1,n} \\ \vdots & \ddots & \vdots \\ a_{n,1} & \dots & a_{n,n} \end{bmatrix} (t) \begin{bmatrix} p_1 \\ \vdots \\ p_n \end{bmatrix} (t) + \begin{bmatrix} (1+r_1) & & 0 \\ & \ddots & \\ 0 & & (1+r_n) \end{bmatrix} (t) \begin{bmatrix} p_1 \\ \vdots \\ p_n \end{bmatrix} (t) \tag{1.53}$$



Perrings starts from a set of initial prices, and then study the necessary conditions on the distribution variables and the technology in order to stabilize the price vector, i.e. the necessary conditions under which the “system can converge to an equilibrium rate of growth” (Perrings (1987)).

With a stable technology, if there is a uniform rate of rents on all processes, Perrings shows that the price system is stable only if this uniform rate is equal to the physical maximum rate of surplus  $R$  (relative prices are stable in the absence of joint production if the uniform rate of surplus is between 0 and  $R$ ). If the rates of rents are not uniform, but stable in time, the stability of the price system is ensured when the price vector is an eigenvector of the socio-technical matrix  $\mathbf{B}^{-1}\mathbf{A} [\mathbf{I} + \mathbf{D}_{r_j}]$  (Perrings (1987), p. 74). But as a result of hypothesis 2, the rates of rents may at the same time be non-uniform and non-constant in time.

In order to demonstrate this, Perrings links the rate of rent of a resource to the excess demand on this resource. Excess demand is the difference between the demand and the quantity produced of the resource; then the rate of rent increases if the excess demand is positive, and *vice versa* (Perrings (1987), p. 75). Let  $\mathbf{q}_E$  be the line vector of excess demand, system 1.52 becomes:

$$\mathbf{B}\mathbf{p}(t+1) = \mathbf{A} [\mathbf{I} + f(\mathbf{q}_E(t))] \mathbf{p}(t) \quad (1.54)$$

This system can only engender a price stability if the excess demand vanished in the long run:

$$\lim_{t \rightarrow \infty} \mathbf{q}_E(t) = \lim_{t \rightarrow \infty} \mathbf{q}(t) [\mathbf{A} - \mathbf{I}] = \mathbf{0} \quad (1.55)$$

Of course this stability of the price system is not possible if environmental resources and processes are introduced, as the hypothesis of a time-independent technology can not hold anymore. Without free gift and free disposal, inventions and innovations are needed.

Now arises the question on the existence of free gift and free disposal, a question we can restate as: why is there no price on environmental resources? For Perrings, there is value when there is property. If there is no value on a resource used by the production system, then there is an exaction: there is no recognition of any property rights on this resource. But this ownership is not just a claim in Perrings system: there can be a rent only if the resource is owned, but also valued, i.e. if the process of production of that resource uses at least one positively priced resource. As Perrings states it:

“resources are economically scarce when their utilization in the process of a human economy implies the commitment of positively valued resources to secure their possession. The term possession has a very precise meaning here. The commitment of positively valued resources to the exaction of environmental resources implies that the latter are possessed and so endowed with value” (Perrings (1987), p. 80).

Thus the terms “production” and “process of production” come with a special meaning in Perrings: labor force is *produced* through the consumption of priced commodities by workers. Thus the wage depends on the claim of the wage earners on the sharing of the surplus but also on the level of consumption goods required for the process of production of labor. A natural resource is produced when there is a need to buy some resources to ensure its protection. The level of the rent on that resource depends on the claim from the owners on the sharing of the surplus and on the required level of protection. It means that for Perrings, a resource is endorsed with value only when it is appropriated and produced: in his system, labor and natural resources are produced because some consumption is necessary in order to ensure their reproduction.<sup>39</sup>

Thus prices reflect claims about rights of ownership and costs induced by these rights of ownership. But prices does not reveal externalities, because externalities are related to exaction or insertion, i.e. to then non-recognition of ownership rights:

“an environmental effect may accordingly be defined as the change in the value of the outputs of a given economic process or processes resulting from a quantitative or qualitative change in the inputs exacted from the environment by the process(es) due to exactions on or insertions into the environment by the same or some other process(es)” (Perrings (1987), p. 84).

He considers in that sense that markets are incomplete if they do not consider the protection costs on environmental resources: for him, this lack of consideration is the source of negative externalities concerning the environment, for instance the over-exploitation of natural resources (Perrings (1987), p. 91).

Perrings thinks that the solution lies in a stationary state of the economy, where the growth rate of the economy is equal to zero (Perrings (1987), p. 141). The overall economic production would remain stable, but the sectoral productions could vary, as well as the prices. Decisions on the exploitation rate and the pollution of natural resources should be socially selected, because it is a matter of ethics, before being a matter of profits. The price system is thus not the good signal to manage environmental problems: the goal should be to use environmental signals to limit interactions with the environment instead of trying to control everything. Quotas of extraction, a solution advanced by Daly in his description of a steady state economy (Daly (1992)), could be a solution.

### 1.2.2.3 Discussion

Curiously Perrings thinks that in this kind of stationary economy, technological innovation would be lower than in competitive, profit-driven, economy. He

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<sup>39</sup>On the contrary, LIPIETZ, for instance, considers that a rent can arise as soon as ownership is claimed, without the need for any consumption linked with this ownership Lipietz (1979)).

justifies that assumption by referring to the old societies which, for him, were not innovative enough to be resilient in case of environmental catastrophe. This assumption, related to the widespread thinking that pre-capitalist societies were not efficient in the use of their capacities, is criticized by Burkett:

“Perrings [has an] impoverished conception of how pre-capitalist economies regulate their exactions from nature. He treats their individual sub-units as homogeneous, self-sufficient, and uninnovative. In the real world, we find that pre-capitalist systems have developed a variety of common property devices internally tailored to the variegated natural environments on which they depend for their reproduction. Often, as these devices have been passed down from one generation to the next in culturally embedded ways, they have been consciously developed to enhance communities’ ability to live and prosper with nature” (Burkett (2006), p. 238, see also Ostrom (1990)).

An other difficulty arises when Perrings, in order to solve the problem of externalities, wants to introduce environmental bonds in order to get a “social control of external effects” (Perrings (1987), p.164): those bonds would be paid by scarce resource users in order to compensate for the social cost of the irreversible loss, in accordance with the polluter pay principle. The price of each bond will correspond the higher probable social cost. In the same way, for the use of a polluting substance, the user would pay to the society a bond equal to the higher probable social cost. The problem of that solution is of course: how to measure social cost? Perrings explains that the price should be decided socially, but this does not really help. Again this proposal shows that the capitalist way of production and distribution is not contested

Finally the whole value approach is said to be inspired by Sraffa’s approach, but Perrings makes some assumptions that are not Sraffian. First, Perrings is wrong when he asserts that Sraffa’s system is a closed one, that can never contract nor expand (Perrings (1987), p. 6). The Sraffian model describes a valuation process, not a physical process (this valuation process is of course based on the physical conditions of production, but can not be reduced to them), and prices at one period of production do not convey any signals about what and how the economy is going to produce in the next period. They just reflect the conditions of production and the distribution of the surplus in that period. Secondly Perrings’ system of value is not Sraffian, as prices at the beginning of the period are not the same at the end. Thus prices in Perrings’ model depends on initial prices. But how to set this initial prices? This is not known.

Let us come back to Perrings’ system of value:

$$\mathbf{Bp}(t + 1) = \mathbf{A}[\mathbf{I} + f(\mathbf{q}_E(t))] \mathbf{p}(t) \quad (1.56)$$

Prices are cost of production that depends on input prices of the previous period, and on the claim on value added that each owners of resource tries

to make (rents on resource). This is very far from Sraffa's development as in Sraffa's case, all value added could be related to labor. And then when Perrings links the rent on each resource to the excess demand, we are coming back again on neoclassical tracks, as prices become also dependent on subjective demand. And a difficult question arises: how to measure excess demand?

### 1.2.3 O'CONNOR: rent and environment as the origin of basic goods

O'Connor (O'Connor (1993b)) continues in the same footing as Perrings (Perrings (1987)), developing an economy-environment model inspired by Sraffa (1960) and Von Neumann (1945-1946)<sup>40</sup>.

O'Connor thinks that:

“the neo-Ricardian framework can be extended to permit analysis of such questions as the use of irreplaceable natural resources and environmental amenities, and aspects of value system conflicts associated with incompatible uses of such resources” (O'Connor (1993b)).

He focuses on:

“the use of 'ecological capital', which may be understood to cover stock natural resources, the ecological systems that furnish renewable resource flows and life-support services, and also non-industrial economies that are vulnerable to predation by an expanding modern economy” (O'Connor (1993b)).

This ecological capital may be “unique and irreplaceable” and “not reproducible by industrial processes”, and the economy needs this capital in order to produce values. Then for O'Connor, “inevitably ... we see conflicts of interests concerning the appropriation and use of ecological capital”. As the economy needs the ecological capital and can not produce it, it becomes scarce and conflicts arise about its uses.

In order to highlight these conflicts, he builds a neo-Ricardian model of production, representing economic and ecological processes. Joint production is allowed, and each process uses at least one input. The matrices of technology (**A** for input, **B** for output, both positive matrices) are assumed to be square (same number of processes and resources); processes are displayed in rows, and

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<sup>40</sup>But curiously he starts his work with a definition of scarcity (“a resource or service is defined to be scarce if its use incurs a significant positive opportunity cost for society, either elsewhere or in the future”, O'Connor (1993b)), and links that with the fact that environmental resources may have no price (“free goods”) if they were non scarce. This relation between value and scarcity is actually really neoclassical, and opposed to the view of Sraffa (where it is production which leads to value, not scarcity).

resources in columns. Fixed coefficient are assumed<sup>41</sup>, only material resources are presented<sup>42</sup>.

He works with a system where environmental and economic processes are interdependent, but interdependence has not the same meaning than in Sraffa, as there is not always in O'Connor's examples one basic commodity linking all processes. The physical system can be represented in this way:

$$\mathbf{y}(T) \mathbf{B} = \mathbf{y}(T) \mathbf{A} + \mathbf{s}(T) \quad (1.57)$$

With  $\mathbf{y}(T)$  the line vector of processes activities and  $\mathbf{s}$  the line vector of the surplus. The available quantity at the beginning of the period of production is thus:

$$\mathbf{q}(T) = \mathbf{y}(T) \mathbf{A} \quad (1.58)$$

And at the end of the period:

$$\mathbf{q}(T + 1) = \mathbf{y}(T) \mathbf{B} \quad (1.59)$$

If there is no free gift and no free disposal, then the produced quantity at the end of the period is equal to the quantity used in production in the beginning of the next period, that is:

$$\mathbf{q}(T + 1) = \mathbf{y}(T + 1) \mathbf{A} \quad (1.60)$$

$$\mathbf{q}(T + 1) = \mathbf{y}(T) \mathbf{B} = \mathbf{y}(T) \mathbf{A} + \mathbf{s}(T) = \mathbf{y}(T + 1) \mathbf{A} \quad (1.61)$$

Thus depending on the initial activity vector, quantities in the surplus vector  $\mathbf{s}$  are positive or negative. Then quantities of the different resources and activity levels of the different processes will increase or decrease from periods to periods. At one point, it is possible that they become negative: it means that the system have broken down. Thus "feasible time paths for the ensemble are restricted to non-negative solutions for a sequence  $\mathbf{y}(T)$ ,  $\mathbf{y}(T + 1)$ , ..." (O'Connor (1993b)).

But O'Connor does not only want to analyze feasible paths, but furthermore paths that allows for a "balanced growth" (O'Connor (1993b)), in reference to

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<sup>41</sup>Because this assumption helps to "bring out the force of the key notions of irreplaceability and non-substituability of ecological capital and allows us to express starkly the idea of value system conflict in resource use and control". Actually, as I think that this assumption is not needed, the sake of simplicity, because he wants to express the dynamics of the economy-environment system, is the only real reason to use it.

<sup>42</sup>As in Perrings Perrings (1987) (and some others authors like Patterson Patterson (1998)), there is, in O'Connor, a need to represent all physical exchanges, and to relate values to these physical exchanges. But in Sraffa, value is connected to the exchange of marketed goods and services between agents, thus it is not necessarily related with material exchanges (the service sector, for instance, can be represented in Sraffa).

Von Neumann's model (Von Neumann (1945-1946))<sup>43</sup>, i.e. with a uniform rate of growth for all processes. Mathematically that adds the following constraint:

$$\mathbf{s}(T) = g\mathbf{y}(T)\mathbf{A} \quad (1.62)$$

With  $g$  the uniform rate of growth. System 1.57 can be, now, written in this way:

$$\mathbf{y}(T)\mathbf{B} = (1 + g)\mathbf{y}(T)\mathbf{A} \quad (1.63)$$

Thus the activity vector  $\mathbf{y}(T)$  must be a eigenvector of matrix  $\mathbf{AB}^{-1}$ .

By considering a global system where natural resources are in limited supply, the available quantities in the beginning of the period of production  $T$  are only the ones produced at period  $T - 1$ . Then constant growth of the economic sub-system can only be fulfilled by a decreasing activity of other subsystems : "balanced *growth of the economy* will then mean proportional growth from one period to the next of the *subvector of those resources valued by economic proprietors*. The ensemble activity may then be 'unbalanced'" (O'Connor (1993b)). And constant growth of all the system is not possible ( $g$  must be equal to 0, see O'Connor (1993a) for a longer discussion on Spaceship earth models, with an account of matter and energy flows).

About the price system, O'Connor first assumes that there is only one rate of profit, allowing for a "balanced economic expansion" (O'Connor (1993b)). This assumption is not related to the interdependence of all processes, but to the economic competition between processes (in a Von Neumann's way). The price system is thus written as follows:

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<sup>43</sup>In Von Neumann's approach, "goods are produced not only from 'natural factors of production', but in the first place from each other"; joint production is allowed; fixed capital is represented - "wear and tear of capital goods are to be described by introducing different stages of wear as different goods, using a separate [process] for each of these" (Von Neumann (1945-1946)). Von Neumann assumes that there are more techniques of production (i.e. processes) than goods to produce. The goal of the model is to define the more profitable techniques of production, such that each commodity is produced by only one process. All processes use at least one input or produce at least one output. The wage is defined in an exogenous way and distributed at the beginning of the period of production. The surplus is totally reinvested, and the model allows only one rate of growth and one rate of interest (equal to the rate of profit). Demand for consumption goods ("necessities of life") is expressed by a row in matrix  $\mathbf{A}$ . If there is excess production, the price of the good becomes equal to zero, and if one process is not as profitable as the uniform rate of profit, it is not operated. Von Neumann demonstrates that a solution can always be found and that the rate of growth must be equal to the rate of interest. The difference with O'Connor is that there are no scarce resources (all natural resources are "free goods") and there is "free disposal" (if there is excess production, the price is just set to zero). The difference with Sraffa is that Von Neumann's system is supposed to operate at equilibrium (one rate of profit), where Sraffa never assumes such equilibrium; both theory finds the same result in single production, with the same number of processes than resources (Kurz and Salvadori (1992)), but Sraffa's theory could also describe a system with several different processes operating the production of the same good (a rent would appear, whereas in Von Neumann, only the more profitable would operate), and could describe a system with different rate of profits, one for the basic processes, and several different rates for the non-basic processes.

$$\mathbf{B}\mathbf{p} = (1 + \pi)\mathbf{A}\mathbf{p} \quad (1.64)$$

### 1.2.3.1 First example

In a very simple example with two processes, O'Connor represents the economy as a single process producing a non basic good 1, in opposition with the environment which produces a basic good 2. He thus takes the opposite view as the one of Sraffa (1960), who represents natural resources as the equivalent of non-basic goods, because there are not produced by the system. In the O'Connor's system, then environment is produced *and* is the support of human activities. The input output representation is thus, with the first process the economic one, and the second the environmental one:

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} \\ 0 & a_{22} \end{bmatrix}; \mathbf{B} = \begin{bmatrix} b_{11} & 0 \\ 0 & b_{22} \end{bmatrix} \quad (1.65)$$

Then, for O'Connor, there are two solutions for the price system 1.64, as matrix  $\mathbf{B}^{-1}\mathbf{A}$  has two eigenvalues. These two solutions leads to two different sets of prices and two different rates of profit. The first eigenvalue is equal to

$$\lambda_1 = \frac{a_{11}}{b_{11}} = \frac{1}{1 + \pi_1} \quad (1.66)$$

With  $\pi_1 = (b_{11} - a_{11})/a_{11}$  the own-growth rate of the economic good. The price solution is  $[p_1 = 1; p_2 = 0]$  when  $\pi_1$  is the chosen uniform rate of profit. The second eigenvalue is equal to:

$$\lambda_2 = \frac{a_{22}}{b_{22}} = \frac{1}{1 + \pi_2} \quad (1.67)$$

With  $\pi_2 = (b_{22} - a_{22})/a_{22}$  the own-growth rate of the ecological good. If  $\pi_2$  is the chosen uniform rate of profit, then both prices are strictly positive if  $\pi_2 < \pi_1$ . If this is not the case, we are in that special case treated by Sraffa as the beans problem (Sraffa (1960), Appendix B): process 1 uses too much of his own product as an input to be able to produce the same rate of profit as process 2. Thus if we want both prices to be positive, the rate of profit of process 1 should be lower than  $\pi_2$ .

For O'Connor, the choice between these two solutions is a matter of "value system contest", i.e. a political decision between owners of the two processes. In O'Connor terms,

"suppose now that each of processes 1 and [2] represents activity managed by distinct societies, each proprietors of their own 'capitals'. Let process 1 be a 'modern' industrial economy geared to expansion and let process [2], the para-economy, be a 'traditional' society geared to self-reproduction. The economy depends absolutely on obtaining inputs of ecological capital. The proprietors of the modern economy might, to ensure positive or at least

non-negative value growth, rely on one of two strategies: (i) *force majeure*; or (ii) success in inducing the proprietors of the traditional para-economy to 'alienate' their capital (resource [2]), and to allow it to be used in the service of economic capital accumulation" (O'Connor (1993b)).

His point is that each solution represents a way to capitalize nature. The first solution is the "free goods" solution: the environmental good is extracted without any compensation. In this case, O'Connor shows that representing in the value system only the economic good, or representing both goods, but with  $\pi_1$  as the uniform rate of profit, leads to the same result in terms of valuation. The second solution represents also a capitalization of the ecological process as the ecological good becomes a commodity and a part of a capitalist system of production and accumulation.

Both solution for the valuation of the goods does not have any relation with the sustainability of the system. On the physical side, there can be a uniform rate of growth  $g$  with strictly positive activity levels of both processes only if  $g = \pi_1$  and  $\pi_1 < \pi_2$ . If there is no free goods allowed and no free disposal, it means that  $\pi_2 = 0$  and  $\pi_1 = 0$ , thus the only sustainable vector of activity level would be  $[y_1 = 0; y_2 = 1]$ .

But what would Sraffa say about this example? For Sraffa, the only rate of profit that we can calculate is the standard one (i.e. maximal rate of profit of the system, as there is no wage) and it is obtained through the construction of the standard system, i.e. through the elimination of non-basic processes. The standard rate of profit is thus  $\pi_2$ , and the prices can then be calculated. Sraffa calculates natural prices, but the question of O'Connor is relevant: what if the price of a resource is imposed? This is effectively done when one does not represent the ecological good in the matrices of technology (this raises the following question: who is the person writing the equations? The question about the valuation process arises here). This could also be done when one dominant industry forces its suppliers to lower their prices, and thus to lower their rate of profit. This is the question of the relation between natural prices (or accounting prices) and what is actually observed in reality.

### 1.2.3.2 Second example

Then O'Connor looks at the treatment of waste: in his second example, the economic processes does not need anymore the ecological good, but jointly produces a waste (good 3) with the economic good 1. A new process 3 appears in order to dispose this waste, through use of the waste and the ecological good as inputs. The input output representation becomes:

$$\mathbf{A} = \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & a_{32} & a_{33} \end{bmatrix}; \mathbf{B} = \begin{bmatrix} b_{11} & 0 & b_{13} \\ 0 & b_{22} & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad (1.68)$$



Looking at the system 1.64, he found again that there are only two possibilities for a uniform positive rate of profit,  $\pi_1$  and  $\pi_2$ . The first solution is again associated with a strictly positive price only on the economic good: [ $p_1 = 1$ ;  $p_2 = 0$ ;  $p_3 = 0$ ]. It can mean again that there is a forced free disposal imposed by the dominant economic sector. The second solution can lead to a price vector where  $p_1$  and  $p_2$  are strictly positive, but  $p_3$  is negative. This negative price is not a problem for O'Connor as the good 3 is a waste<sup>44</sup>. This solution again is interpreted by O'Connor as an example of "coercion by the economy over the para-economy, where the latter's proprietors are making the best of a situation they did not choose to enter" (O'Connor (1993b)).

What would Sraffa say about this example? First there is no interdependence between all processes: there are two basic goods (the economic good and the ecological good), but neither the economic process nor the ecological process need the other to operate. Only the waste disposal process needs both processes to operate: but as this process does not produce anything, it is a non-basic process. So actually system 1.64 shall not be used in this case: the economic process operates with the profit rate  $\pi_1$ , the ecological process operates with profit rate  $\pi_2$  and the waste disposal process operates at a profit rate equal to zero, as "the net value of inputs in process 2 is zero by construction". This last process should not be represented like this, anyway: what is produced by the waste disposal process is "the service of waste disposal". Then system 1.68 should be represented in this way:

$$\mathbf{A} = \begin{bmatrix} a_{11} & 0 & a_{33} \\ 0 & a_{22} & 0 \\ 0 & a_{32} & 0 \end{bmatrix}; \mathbf{B} = \begin{bmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{13} \end{bmatrix} \quad (1.69)$$

In this way, the waste disposal process produces a service that can receive a positive price, and the owner of that process can receive a positive rate of profit<sup>45</sup>. And we thus come back to the problem of the first example, where the economic and the waste disposal processes are non basic and the ecological process is basic: we find the same results.

### 1.2.3.3 Third example

Finally O'Connor looks at the general case where rates of profit are different depending on the processes. This is for him justified as:

"both the definition of what shall be the prevailing value system  
and the distribution of any 'surplus value' defined in terms of this

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<sup>44</sup>We can find the same logic with a negative price attached to a waste in Kurz and Salvadori (1992).

<sup>45</sup>This misrepresentation can be interpreted as a desire to represent physical exchanges between industries, where Sraffa's system is designed to represent exchanges of marketed commodities and services. And both flows does not always correlates. This wrong logic is close to the attempts to represent ecological prices (for instance we can find the same kind of mistakes in Patterson (2002)).

system, will depend on outcomes of a military and/or political process ... In general, the outcomes of this political process will remain somewhat indeterminate and there will continue to be evidence of several wholly or partially overlapping, unreconciled, more or less incompatible value systems. Profit equalization is a most implausible outcome of such a power struggle and to assume it obscures the underlying conflict”<sup>46</sup> (O’Connor (1993b)).

The value system becomes now:

$$\mathbf{Bp} = (\mathbf{I} + \mathbf{\Pi}) \mathbf{Ap} \tag{1.70}$$

With  $\mathbf{\Pi}$  the diagonal matrix having in its main diagonal the different rates of profit; unlike Perrings (Perrings (1987)), he assumes that the owners of similar processes (and not the owners of similar resources) are the ones likely to join forces into one class. This representation is clearly close to mark-up pricing as represented for instance in some post-Keynesian works (e.g. Lavoie (1996), see also Kemp-Benedict, section 1.3.4); then again we come back the question of the relation between the natural prices and what is actually observed in reality. The difference may lie in the rents that everybody tries to capture. For O’Connor, “the rate(s) of return and relative prices that *actually* prevail can be thought of as kinds of distributional parameters indicating the outcome of the contest over purposes of productive activity and over appropriation of the surpluses” (O’Connor (1993b), emphasis added). In his examples, they should be seen as “an indicator of the intensity of dominance exercised by the economy over the para-economy, or *vice versa*” (O’Connor (1993b)). But more empirical work should be done to study this relation.

In a last example, he complicates further system 1.68 by adding a fourth resource, an ecological waste produced by the ecological process, and a fourth process, disposing the ecological waste through the use of the economic good. We find again the same problems as in the second example: O’Connor claims that the processes are interdependent where actually the system is composed of two independent sub-systems (the economic and the ecological), with two non-basic processes in between:

$$\mathbf{A} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ 0 & a_{22} & 0 & 0 \\ 0 & a_{32} & a_{33} & 0 \\ a_{41} & 0 & 0 & a_{44} \end{bmatrix}; \mathbf{B} = \begin{bmatrix} b_{11} & 0 & b_{13} & 0 \\ 0 & b_{22} & 0 & b_{24} \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \tag{1.71}$$

And again the two processes of waste disposal produce nothing, when the logic of Sraffa would command to represent them as producing services, in the following way:

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<sup>46</sup>He also justified this approach by referring to Perrings, who argues that “an assumed high degree of complementarity of resources means that there is no mechanism to ensure the equalization of returns to all factors” (O’Connor (1993b)). But actually interdependence between processes can ensure that a uniform rate of profit will emerge, even if inputs are complementary.

$$\mathbf{A} = \begin{bmatrix} a_{11} & 0 & a_{13} & 0 \\ 0 & a_{22} & 0 & a_{24} \\ 0 & a_{32} & 0 & 0 \\ a_{41} & 0 & 0 & 0 \end{bmatrix}; \mathbf{B} = \begin{bmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & 0 & b_{44} \end{bmatrix} \quad (1.72)$$

Then we have a system with interdependent processes, and four basic goods. Thus only one rate of profit is possible. Ironically this example is used by O'Connor to investigate precisely what happens when different rates of return apply. He finds that those rates of profit can signal “outcome of the struggle over the reciprocal imposition of a waste-disposal burden”.

O'Connor analysis goal is to understand how nature is capitalized. This process may include rewards for the ecological production, but in any case there is no connection between capitalization of nature and increase in sustainability: “if the picture painted by our model has plausibility ... economic progress may not be sustainable value growth under any interpretation” (O'Connor (1993b)). Furthermore he recalls in conclusion that “there is no 'general' treatment of economy-environment dynamics once the features of irreplaceable and/or depletable resources and of value system contest are introduced” (O'Connor (1993b)): indeed the relations between societies and there environments have always been complex and variegated.

#### 1.2.4 COGOY

In his article “Market and non-market determinants of private consumption”, Cogoy (1995) is asking an interesting question: what would be the impacts of including the “consumption process” inside the market? Consumption is here “viewed as a process having enjoyment targets as outputs and requiring market and non-market inputs”: it represents the time spent in supermarkets, repairing the house to have a comfortable dwelling, waiting at the gas station, etc.

Then, considering this “process”, he looks what are the changes if a company decides to sell the “consumption” service:

- on the economic side, will there be more or less profits? Using Sraffa, he shows that the rate of profit would not change (as the service “consumption” is a non-basic good) but that the volume of profit would increase.
- On the efficiency side, he wonders if it will be less time-consuming, thus if it will increase the leisure time for the workers (the time spent in the consuming process would be available for leisure, but in order to buy the “consumption” service, workers would have to work more).
- On the environmental side, he asks the question whether there will be an increasing awareness of environmental concern.

On all that points, there is no definite answers: it could be interesting to have a private sector for consumption, but it will not be interesting if the institutional

and cultural contexts are not well taken into account. Depending on them, it could even be more interesting to go backward and to remove from the market some services.

This analysis is done along three different aspects (economy, efficiency and environment): there is no attempt to connect these aspects into a more global system. Sraffa is just used to illustrate the case; there is no real attempt either to integrate Sraffa into the ecological economics framework<sup>47</sup>. But anyway the question of whether we need to integrate the consumption process (and why not even the “leisure” process) into the analysis is a good question: this is related to the question of the definition of the surplus of the economy. Should we take into account in the definition of surplus everything which is not consumed by an industry, or should we deduce from that what is necessary to live (the means of subsistence)? The second option was chosen by Smith and Ricardo<sup>48</sup> but the first one is more easy, maybe less arbitrary and was chosen by Sraffa.<sup>49</sup>

### 1.2.5 MARTINEZ-ALIER

Martinez-Alier (1995) is interested into distributional issues, i.e. how the wealth created by the economy is distributed among classes of population and among nations. He claims that the main concern of political economy is distributional conflicts. One famous (theoretical) distributional issue is what is called “the internal contradiction of capitalism”:

“firms are individually inclined not to pay high wages, and therefore there might be a lack of effective demand from households in the aggregate to buy all the goods and services which would be available with production running at full capacity utilization” (Martinez-Alier (1995)).<sup>50</sup>

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<sup>47</sup>And there is some misunderstandings of Sraffa, e.g. in “the [Sraffa] methodology ... would have to be modified if more complex features of the economy, such as joint production, increasing return to scale, wage differentials, non-competitive markets, etc. were considered”. I claim that this is wrong, and that the Sraffa system can cope with all this point without being changed.

<sup>48</sup>Martins Martins (2013) recalls that Smith and Ricardo not only deduce from the surplus what is necessary to survive, but also what is necessary to achieve “a certain level of well-being according to what is customary” Martins (2013).

<sup>49</sup>On that point, Richard Arena, during meeting in October 2014 in Nanterres University, Economix, recalled that it is not that easy to separate what is needed by the industry and what is superfluous. For instance, is the coffee break part of what is necessary in order to perform the process of production? Or is the coffee a part of the surplus consumed by the worker?

<sup>50</sup>This contradiction is also described by Castoriadis (1979): “le capitalisme, au contraire [des formes sociales qui l’ont précédé], est bâti sur une contradiction intrinsèque – une contradiction vraie, au sens littéral du terme. L’organisation capitaliste de la société est contradictoire au sens rigoureux où un individu névrosé l’est : elle ne peut tenter de réaliser ses intentions que par des actes qui les contrarient constamment. Pour se situer au niveau fondamental, celui de la production : le système capitaliste ne peut vivre qu’en essayant continuellement de réduire les salariés en purs exécutants – et il ne peut fonctionner que dans la mesure où cette réduction ne se réalise pas ; le capitalisme est obligé de solliciter constamment la participation des salariés au processus de production, participation qu’il tend

A second contradiction of capitalism is described by James O'Connor (1994a): the accumulation process leads to produce more with lower costs, but the environment cannot endlessly give us cheap resources. Indeed, ecological processes of production follow their own rhythms and if resources become more scarce, their price could increase. But this is conditional, because it depends on distributional issues: the allocation of property rights and the allocation of income, between present and future generation.

First everything have a price if someone asks for it. If we are looking at produced goods, workers and capitalists ask for a price, the firsts in order to be paid for the labor time, the seconds because they are the owners of the goods. If we look at natural resources, then there is no worker asking for a reward, but there still can be owners to ask for a price on the use of the resource (or to ask for compensation if the resource has been destroyed): for example the rentier who asks for a rent on his land. There arise the question of the allocation of property rights on nature. This allocation is always the result of a political process, and it could be the result of a democratic deliberation or of a violent conflict (i.e. it is also the result of power relationships). But of course some natural resources and services are not allocated. The question Martinez-Alier asks is: who is willing to take care of this resources? For instance:

- “Are there owners of the Earth’s ability to recycle a good part of the CO<sub>2</sub> pumped by humans into the atmosphere?”
- “Are there owners capable of evaporating water and making it fall again in places where water is scarce?”
- “Are there owners of wild and agricultural biodiversity, partly yet uncatalogued?” (Martinez-Alier (1995)).

Here Martinez-Alier is not saying that all natural resources and services should be privately owned, but rather that people and companies that are destroying these resources are acting as if they were their owners. Thus there is a need for someone to say: “this is not your property” or “this is also my property, and the property of my children”, so a discussion about the protection or not of the resource can start.

“For instance, we Europeans pay nothing for the environmental space we are using in order to dispose of our emissions of CO<sub>2</sub>... Valuation of externalities depends on the allocation of property rights. In this case, the Europeans acts as if we owned a sizable chunk of the planet outside Europe, but (almost) nobody is yet complaining, or trying to charge us a fee” (Martinez-Alier (1995)).

Then arises the problem of the level of the payment if a resource has been destroyed (how to value externalities), or the level of the price if there is a transaction. This price also depends on distribution of income. “The poor sell

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par ailleurs lui-même à rendre impossible” (cited in Boltanski and Chiapello (1999)).

cheap” principle, or “Lawrence Summers’ principle” (Martinez-Alier (1995)) tells us that:

“the measurement of the costs of health impairing pollution depends on the foregone earnings from increased morbidity and mortality. From this point of view a given amount of health impairing pollution should be done in the country with the lowest cost, which will be the country with the lowest wage” (Summers (1992), cited in Martinez-Alier (1995)).

An application of this principle can be found in the Texaco vs. Ecuador case, where:

“Texaco was involved in the extraction of oil from the northern part of the Amazonian territory of Ecuador since the early 1970s until 1990. Damages [arisen] from oil spills, deforestation, disruption of the life of local indigenous communities”.<sup>51</sup>

In the beginning of this case, the following question arose: should Texaco-Chevron, a US company, pay the US price for damages, or the Ecuadorian price? As Ecuadorian were a poor people, Texaco asks for an out-of-court settlement: “the out-of-court settlement being discussed in the fall of 1994 ... seemed to imply a payment by Texaco of about ... one hundred time less than the damages being sought in court”.

And finally arise the question of the distribution of ownership and income between generations. If there is irreversible damages, should we take into account the use value which is lost? In this case, what discount rate may apply? Martinez-Alier refers to a “fair” positive discount rate when there is expectation of an increase of the technological capacity of production with the same (natural) capital: “investment sometimes increases productive capacity”. Thus future generations may produce the same amount of wealth with less natural capital and this is why we may value the future use less than the present one. But of course investment sometimes destroys natural productive capacity, and thus it is not easy to know if future generation will produce enough wealth with enough natural capital. And it is not because we have found the just discount rate that the value of the initial capital is fair<sup>52</sup>.

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<sup>51</sup>The case is still under consideration: in 2011, a independent Ecuadorean court ordered Chevron (the new owner of Texaco) to pay \$9.5 billion, but in 2014 the U.S. District Court for the Southern District of New York finds that the Ecuadorian judgment was unenforceable.

<sup>52</sup>This question on the discount rate relates to the question of the “just” or natural rate of interest investigated by Pasinetti (Pasinetti (1993, 2001)). For him, the rate of interest should be a rate “which maintains unaltered through time the purchasing power of all debt/credit relations in terms of labour” (Pasinetti (2001)). Why in terms of labour? Because this is a unit of value (time spent doing work) which is not supposed to change through time. Thus when a lender gives to an investor the money he won during one hour of work, he shall be able to receive in the future the equivalent of one hour of work. And if the investment increases the productive capacity, then he shall receive more money than before, because one hour of work has became more productive.

And we can add to future use value, option value (the resource is not yet used, but could be in the future) and existence value (the resource has an ethical right to exist). This last item is interesting because we are going outside of the scope of distributional issues: for instance, “the Texaco case provides example of attempts to put present money values to the unknown loss of biodiversity” (Martinez-Alier (1995)). Here the problem becomes: how can it be possible to put a value on something which has no connection to any economic activity? Economic value express the utility for society of a given thing, or the fact that this thing has been appropriated by someone; but in the case of existence value, there is no such relation. This is the issue of incommensurability: the measure of value does not apply to everything. But even if there is not a common unit of measurement, “it does *not* mean that we cannot compare alternative decisions on a rational basis, on *different* scales of values, as in multicriteria evaluation” (Martinez-Alier (1995)).

In the Texaco’s example, the price depends on the income of the owner, i.e. on income distribution. This relation between price and distribution of income is not the same in neoclassical and Sraffian economics. In neoclassical economics, income is the result of marginal productivities of factors of production (capital, labor, land) and “if the distribution of income is changed (for instance, by fiscal redistribution), then the pattern of demand and therefore the pattern of prices would change” (Martinez-Alier (1995)). This latter relation is more direct in Sraffian economics: if the income distribution changes, price will directly change, even if demand is kept constant. And income distribution does not depends on marginal productivities, but is a result of a power struggle. That is why Martinez-Alier claims that Sraffian economists are more close to political economy issues, as they claims that there is no “true value” of the services of labor, capital or nature (only a political process can assess these values), than neoclassical economists.

Martinez-Alier remains careful about the possible application of Sraffian economics:

“Assuming there would be a Sraffian ecological economics, we would need first to decide which items belong to ‘natural capital’ (i.e. are appropriated and by whom), and then we could show how their valuation depends on the distribution of income. Sraffian economics (even if ‘ecologized’) is economics, and therefore it would attempt to explain economic values. It would not deal with the wider issues of ‘ecological distribution’” (Martinez-Alier (1997)).

To develop that latter issue, Martinez-Alier calls for the development of a “political ecology”, which “would study ‘ecological distribution’ conflicts” (Martinez-Alier (1995)). For him, ecological distribution refers to “the social, spatial, and temporal asymmetries or inequalities in the use by humans of environmental resources and services, i.e. in the depletion of natural resources (including the loss of biodiversity), and in the burdens of pollution”.

Martinez-Alier does not know who are the social actors of ecological distribution conflicts (or of the second contradiction of capitalism as described

by O'Connor (1994a)). For him this not a fight for the appropriation of the surplus within the capitalist mode of production between capitalists, rentiers and workers, as in Sraffian models. It is a fight about "reproduction of human society and of nature's functions"; so for him different actors are involved. The result of such conflict can be seen when a price is set in order to compensate for the destruction of an environmental service: the level of this price expresses the relation of power between the protagonists. One important thing is then to understand what this compensation price can cover, and what has been the language of valuation used:

"Are ecological values only valid if they are translated into financial terms, or are they valid in themselves with their units of biomass and biodiversity? Is it valid to argue directly in terms of human health, subsistence and welfare, or do we have to translate them into money? What is the value of a landscape, not in monetary terms, but in itself? How much is human life worth, not in terms of money, but in itself? Hence the question that brings ecological economics and political ecology together: who has the social and political power to simplify complexity and impose a particular language of valuation?" (Pellegrini (2012)).

### 1.2.6 DOUAI

Ali Douai (2009) considers that the classical theory of production prices developed by Ricardo and Marx can be useful to ecological economics. For him, the classical theory makes the distinction between the use value and the exchange value, and thus between the wealth (the sum of use value, etymologically defined by Douai as the conditions of well-being) and the economic production (sum of exchange value). Thus, because it acknowledges the fact that the economy is not aiming (or not uppermost aiming) at satisfying human needs, but at capitalistic accumulation instead (through economic production), leading to the possibility of bad social and environmental consequences, this theory appears more appealing than the neoclassic theory which, following Say, aggregates wealth and economic value into the same unit: "the key idea - which Marx and Engels [Marx and Engels (1975)] attributed to Bentham - is that 'money represents the value of all things, people and social relations'" (Douai (2009)).

The problem is the monetary vision of wealth is dominant, because the neoclassical theory is dominant. Until now, ecological economics have only underline that different systems of value could coexist, that it is not ethical to reduce them to the sole economic value system (problem that occurs in neoclassical Willingness to Pay/Willingness to Accept studies) and that we should build "discursive" institutions allowing the society to solve the problem of non commensurable systems of value. But classical economy could help to go further, by fighting directly the neoclassical vision. Ricardo for instance asserts that:



“[utility] is certainly the *foundation* of [exchange value], but the degree of utility can never be a measure by which to estimate [exchange value]. A commodity difficult of production will always be more valuable than one which is easily produced although all men should agree that the latter is more useful than the former” (Ricardo (1951-1973), cited in Douai (2009)).

For Ricardo, if water would become suddenly a marketed good, with a price (through the private appropriation of the water by a rentier), this would not raise the national wealth: it would just be distributed in a different way. The economic production is not increased and the surplus is the same: only the amount of exchange value has changed. This rent is not connected to human labor or to a phenomenon of differential rent, and then can not be calculated through Ricardo’s (and Sraffa’s) system; but as soon as this rent is assumed in a exogenous way, it will impact the price system (and all prices if water enters into the composition of a basic good) and the economic value of some goods will increase (the maximum rate of profit will not move but the shares of the surplus devoted to the profits and to the wages will be lowered). The Ricardian analysis allows then to distinguish between wealth and price, leaving then a room for the non-monetary evaluation of goods producing use value for humans.

Ricardo defines utility as: “the capacity of things to meet the *’necessities, conveniences, and enjoyments of human life’*” (Ricardo (1817), cited in Douai (2009)). He is then in opposition with Say’s definition (Say (1803 (1972))) of political economy:

“Political Economy [Say] thinks is an enquiry into the nature and causes of wealth; I think it should rather be called an enquiry into the laws which determine the division of the produce of industry amongst the classes who concur in its formation” (Ricardo (1817), cited in Douai (2009)).

Wealth can not be reduced to an owned quantity of exchange value; thus for Ricardo political economy should concentrate its efforts in the understanding of economic production and distribution.

We find again this dichotomy between use value and exchange value in Marx. The first is defined qualitatively and is dependent on the social context, it can not be considered as an economic category. The second is defined quantitatively as the sum of the abstract labors needed to produce the good. There is a social validation of the concrete labor and thus its transformation into abstract labor when there is exchange through the intervention of money. What is important is to understand that wealth is different from exchange value: use value, component of wealth, can come from human labor, but also can be separated from it, and in the first case this human labor can be economically validated or not (it can stay only concrete or become also abstract). As states Marx:

“[one thing] can be a use-value, without having [economic] value. This is the case whenever its utility to man is not due to labour. Such are air, virgin soil, natural meadows, etc. A thing can be useful, and the product of human labour, without being a commodity. Whoever directly satisfies his wants with the product of his own labour creates, indeed, use-values, but not commodities” (Marx (1867), cited in Douai (2009)).

The problem of capitalism is that it is aiming to accumulate exchange values, and only exchanges values: thus there is a pressure to connect all notions of wealth with exchange value, so that all exchanges becomes monetary exchanges. This creates social troubles (true use values becoming less considered) and environmental troubles (again because goods which are not associated with an exchange value are not anymore considered useful). This problem has been described by Marx: the production of use value becomes “an unavoidable intermediate link [...], a necessary evil for the sake of money making” (Marx (1885 (1976), cited in Douai (2009))). And for Marx and Engels this type of reverse reasoning is more and more common because of the development of utilitarian thinking.

Douai resumes the problem on money as an account of wealth in this way:

“the possibility of seeing the value of all things, people and social relations in terms of money is *specific to capitalist conditions*. What utility theory does not say is that money is the material expression of the social character of production and not of utility. When money becomes the general expression of wealth, it expresses: 1) a power: ‘that each individual exercises over others’ activity or over social wealth exists in him as the owner money. Thus both his power over society and his association with it is carried in his pocket’ [Marx (1857-58 (1967-68)]; (2) the effacement of all natural and human qualities” Douai (2009).

From there Douai criticizes ecological economics researchers who agree on one hand with the attempts to give an economic value to an environmental good or service with the help of the neoclassical theory (value of a marginal unit, contingent valuation, WTP/WTA studies, etc.) and on the other hand who highlight the limits of these studies by showing that all systems of value are not taken into account. Indeed they are not, because the goal of the neoclassical theory of value is to express use value with money: it takes for granted that there is a commensurability of *all* systems of value into money (in order to answer the question how is this good useful to society, it reduces the question to: how much this good is useful to society). It is not possible to support both position without contradiction. Thus Douai wants that ecological economics take a more critical stance on economic valuation of nature, keeping in mind that: “economic value (as its monetary form) is an expression of social relations that are exclusively characteristic of capitalism” (Douai (2009)). He is not

saying that nature can not be a support for economic value creation<sup>53</sup> but that nature has no intrinsic economic value.

Douai then criticizes Cost Benefit Analysis, who uses money in a simplistic way as a mean of exchange and of valuation of the use of an environmental good or service, aggregating the pluralities of values, where money, in fact, reflects social relations and supports a specific value system. We can then, in the light of Marx and Ricardo's political economy, understand why, simultaneously, some people will accept to give a price to nature ("since it reflects the alienation of social relations and relations with nature from their real meaning", Douai (2009)) and why others will refuse ("they may associate economic value/money with specific interests or positions in bourgeois society and/or see it as representative of the negation of any specific quality", Douai (2009)).

But classical political economy does not give any clue about the way we could take into account the environment in political decisions (which institutions? which decision models?). And we have to account that environmental conflicts are not only conflicts of values, but also conflicts of power and interests (O'Neill (1997)). It is thus, for Douai, extremely delicate to promote participative democracy or deliberative democracy as the decision model that anyone should adopt in environmental conflicts (a vision that ecological economics usually support) without first a study of the existing social structures (and of the tensions between individual and social values). As says Vatn: "[power] may be built into the basic structures of society – the institutions – like access to resources . . . brute force is transformed into 'the way things are'" (Vatn (2005)). Political economy may help to reveal these power structures and to build a fair environmental policy.

### 1.2.7 BURKETT

Burkett, a Marxist, enters into the debate of the valuation of the environment; for him the purpose of the value analysis is not to "explain exchanges values" (as in Farber et al. (2002)), but to reveal what are the conditions of production and especially how these conditions of production leads to the exploitation of human labor and the destruction of the environment. He offers a Marxist analysis of value, and of the relation between the economy and the environment. For him, use-value means utility, i.e. something providing satisfaction is valuable in terms of use-value. Exchange value is the market price of a commodity: under capitalism, this price does not reflect the use-value of this commodity, but in order to be sold, the commodity must have an use-value. The exchange-value, under capitalism, represents the amount of value embodied in it, i.e. the "abstract, socially necessary labour" performed in order to produce this com-

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<sup>53</sup>He highlights that scarcity can be a source of economic valuation, following Marx: "for Marx, scarcity is also a condition of economic value" (Douai (2009)). He then adds: "[ecological resource] scarcity and usefulness are necessary pre-conditions [to support the production of economic value for capital]". Here scarcity should be understood as "scarce enough to allow for appropriation". Following Lipietz (1979), we can say that scarcity exists as soon as someone privately owns the resource and thus decides who should make use of it.

modity (Burkett (2006), p. 184). “Abstract” because, under capitalism, labor is made uniform through the wage relation. “Socially necessary” because the commodity has an use-value which is reflected in the fact that the commodity can be sold on the market.

But saying that capitalism reduces the exchange value to abstract labour does not mean that only labor can create use-value: nature is also a source of use-values. Furthermore it does not mean that labour is the only necessary condition in order to produce exchange-values: nature is also needed, the third necessary condition being that the commodity must have an use-value:

“Marx ... insists that both nature and human labour contribute to the production of all these use-values. In analyzing commodities and money, he emphasizes that ‘the physical bodies of commodities, are combinations of two elements, the material provided by nature, and labour’. Importantly, Marx also insists that ‘nothing can be a value without being an object of utility. If the thing is useless, so is the labour contained in it; the labour does not count as labour, and therefore creates no value’” (Burkett (2006), p. 184, Marx (1885 (1976))).

Then the concept of exploitation lies in the fact that human labor can produce more than its means of subsistence:

“for Marx, the possibility of surplus-value stems from labour-power’s ‘specific use-value...of being a source not only of value, but of more value than it has itself’. ... The result is an energy subsidy for the capitalist who appropriates and sells the commodities produced during the portion of the workday over and above that required to produce the means of subsistence represented by the wage” (Burkett (2006), p. 191-192, Marx (1885 (1976))).

Burkett describes the alienation of the producers from the conditions of production as a condition for capitalism development:

“This alienated form of exchange only becomes dominant on the basis of workers’ three-fold alienation: from necessary production conditions (including the land), from the production process itself, and from its products. Competitive market exchange and monetary valuation are not just matters of ‘convenience’ in capitalist society. They are necessary social forms of material wealth in a system where workers are socially separated from necessary conditions of production to the point where they must become wage-labourers (work for money) in order to live. ... It is only in this situation that the economy becomes an apparently autonomous, self-regulating sphere vis-à-vis the natural, cultural, and political dimensions of social reproduction and human development” (Burkett (2006), p. 133).

Thus labour becomes a commodity, and nature as well, in order to allow for the expansion of capitalism:

“the conversion of human labour-power and natural conditions into capital is not just a way of thinking, not just ideological, not just a legal-judicial construct, and not even just a commodification of the conditions of human existence: it is a fundamental condition (and contradiction) of capitalism at the level of production relations. ... Under capitalism, human labour-power and nature really are socially separate means of competitive profit-driven production” (Burkett (2006), p. 133-134).

Burkett starts his analysis of the value debate in ecological economics by describing the energy theory of value (Burkett (2003), Burkett (2006), chap. 1) as proposed by Costanza, Hannon, Farber and Wilson (Costanza (1980); Costanza and Neill (1981); Hannon (1998); Farber et al. (2002)). This approach has been mainly criticized because it assumes that the qualities of all factors of production can be reduced to their energy contents (whereas “matter matters too”, Georgescu-Roegen (1979)). Then two approaches tried to offer an alternative to the energy theory of value within the ecological economics field<sup>54</sup>. First an eco-Sraffian approach (Perrings (1987); O’Connor (1993b); Patterson (2002)) uses “Sraffian input-output models to analyze the determination of market exchange values (and related issues of distributional conflict and economic crises), but without treating any single primary input as the unique source of value” (Burkett (2006), p. 19). Then a second track tried to link a flow-fund model of production with a theory where exchange value is not connected with one factor of production and where use-value is defined as “enjoyment of life” (Georgescu-Roegen (1979); Daly (1992)).

Burkett first criticizes the energy theory of value: for him, using Sraffian input-output model to describe natural processes is like assuming that “markets exist for all sources and types of energy used in production including the free solar energy” (Burkett (2006), p. 38, he follows Daly on this point Daly (1981)), which is highly implausible. In fact for him the Sraffian description of the economy is only possible in a capitalist economy, where all resources and labor are reduced to exchanged commodities. In his analysis, a non capitalist economy could not be described by the same model: in a non capitalist society, conditions of productions (i.e. resources and means of production) are in the hands of the workers, and labour-power cannot be separated from his conditions of production. Thus there could not be a uniform wage and a uniform price on each resource, and there could not exist a direct connection between money and wealth in such economy<sup>55</sup>. In his own words:

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<sup>54</sup>There has been also criticism of the energy theory of value from an eco-Marxist point of view (Skirbekk (1994)), but I will not describe it.

<sup>55</sup>This non-capitalist economy would also value nature differently depending on the different community: “only through a real communality, in which people gain control over the social conditions of their existence ..., will society be able to regulate its metabolic interchange with nature in a healthy and sustainable way” (Burkett (2006), p. 54-55).

“the regulation of social production by the market (the imperative for value to be objectified in salable commodities) is itself based on the separation of producers from necessary production conditions. It is true that markets and money have existed for aeons; but the dominant position of profit-driven commodity production, and the constant competitive pressures on the producers, owe themselves to the commodification of ‘free’ labour-power and its employment by autonomous enterprises controlling the (now ‘separate’) conditions of production. The conversion of natural conditions into mere conditions of market- and profit-driven production (either through their free appropriation or through their formal capitalisation as rent-yielding private or state property) is, in particular, enabled by the ‘freeing’ of labour-power from these conditions. This process continues today whenever public or communal lands are privatized, and whenever corporations are given freer reign to exploit national forests and other natural resources” (Burkett (2006), p. 53-54).

Then, as all process of production need some energy, this is not very surprising that a correlation is found between exchange value and energy exploitation. As Daly states, and as Burkett repeats, “this is not ‘a true empirical founding’, but rather an ‘imposed result of the analytical framework’” (Burkett (2006), p. 38, Daly (1981)). But this a dangerous result if it allows for the evaluation of natural ecosystems using market energy prices (Daly (1981)). Actually the question is: why are there market prices? Are they fair? If they represents use-value, as for example Farber, Costanza and Wilson argue (Farber et al. (2002)), then they are indeed fair, and we could use them to value the environment (as there is a correlation between energy use and market prices, and thus between energy use and use-value). But if they are just the representation of the current compromise in the confrontation to possess a share of the surplus between social classes or /and the representation of the current capitalist way of valuation, then the valuation of nature through market prices should be rejected. In Burkett’s own terms:

“the energy theory’s search for a primary input is driven by its reduction of the question of value to that of finding some common measure of use-value conceived apart from historically specific social relations of production. This decision having been made, it is but a short step to the view that money and markets are just convenient social devices for registering these quantitative ‘energy values’ as exchange-values” (Burkett (2006), p. 38-39).

Then he criticizes the Eco-sraffian approach (Burkett (2006), chap. 1 and 8): for him, again, these models fail to consider the specificity of capitalism, i.e. the reduction of labor and resources into commodities. They think they described reality, but they described a capitalist way of representing reality. This capitalist representation is currently effective in most human economies,

but it is not because it is the current state of the economy that it is a fair state and that it has always been the way the economy was regulated. Thus there should not be a need to extend this representation to environmental processes:

“the assignment of monetary prices to ecological use-values, even when they are not priced in reality, complements the ‘tragedy of the commons’ notion that the non-pricing of natural resources and the non-assignment of private or state property rights to these resources explains why they are overexploited, as well as the companion notion of a ‘green capitalism’ which fulfills the resource-pricing and property rights functions more effectively” (Burkett (2006), p. 44-45).

Perrings for instance assumes that the problem of externalities can be solved by using environmental bonds (Perrings (1987)), i.e. a tax that each user of nature resource should pay in order to finance the protection of the resource. Here the problem for Burkett lies also “in the qualitative reduction of natural wealth to *homogeneous* monetary terms” (Burkett (2006), p. 42, emphasis added). To accept monetary exchange in a particular problem of natural resource exhaustion could be acceptable, but to generalize this to all problems, this means capitalizing nature. Even if all partners agree on a price for a natural resource, if this price is generalized on a national or a global level, this means a commodification of nature.

Burkett is also opposed to the analysis of O’Connor (1993b):

“because O’Connor’s model lacks a treatment of the industrial economy’s internal production relations as relations of class exploitation (it does not even distinguish human labourers from other inputs), it must take this economy’s growth imperative as a given. Since the model does not explain this imperative, or how it is related to competition, it cannot explain why rational capitalists (‘industrial proprietors’) would pursue it to the point of their own destruction, or how they are able to get their employees to follow them down this suicidal path” (Burkett (2006), p. 255).

Indeed the social relation of production - the relation between classes - are not explained by O’Connor, and also the dynamics of the system - the reason why there is a need to grow indefinitely - are not clarified.

Burkett deepens this criticism when he talks about the model of England (1986). For him there are three problems with this generalization of the class struggle between environmentalist, workers and capitalists. First the model does not describe the power relations and how this relations are constructed; second there is apparently a collusion of interest between capitalist and workers against the environmentalist, where in reality things are more complex; third, the model does not allow for a capitalist sector of production producing the service of waste disposal. On the last point, we find again the problem of O’Connor representation of the waste disposal sector (O’Connor (1993b)).

Stated differently, “the model does not distinguish pollution control for profit versus pollution control for human needs” (Burkett (2006), p. 275). And this distinction is important as the waste prevention is not a plausible outcome of the first kind of pollution control:

“what is needed is a change in production technology toward greater quality and durability of the goods produced and less total waste generated by production itself. But such a change conflicts with the capitalist imperative to accumulate ever larger quantities of capital through the production and sale of commodities. That is why it can only occur in the context of workers and communities taking control of production and reorienting it toward sustainable human development” (Burkett (2006), p. 276)<sup>56</sup>.

Burkett follows that with a criticism of the approach of Daly and Georgescu-Roegen, although they are not trying to put a value on nature and they are not using extended Sraffian models to represent the interaction between environment and economy. For Burkett the problem lies in their uncritical look on capitalism: for them capitalism has nothing to do with the environmental problems, in the sense that the problem is not how we are producing commodities (what are the conditions of production), but the scale at which we are producing them. But for Burkett, solving the scale problem (by adding resource-depletion and birth quotas to a capitalist way of production) is a curative solution, not a preventive one: the way capitalism separates producers

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<sup>56</sup>On several points Burkett is wrong, or at least goes too far into his critic of Sraffa’s models. First for him Sraffa’s prices are “long-run equilibrium prices” (Burkett (2006), p. 221), where I think that they are just the prices of the current period of production. Second he thinks (in part because of the first point) that Sraffa’s model is too much capitalist, in the sense that the only possibility for social change is rejected in the distribution of the equilibrium long term surplus: “class conflict [in Sraffian models] is ... relegated to distribution, and can play no role in production” (Burkett (2006), p. 228). It is true that Sraffa never talks about class conflicts but I think that the result of one period of production says nothing about the conditions of production in the next period. Prices are the result of the conditions of production and of the distribution of the surplus in that period; in the next period both conditions of production and the sharing of the surplus can change. So when Burkett asserts that “like neoclassical theory, [Sraffian analysis] throws a technical, ahistorical cloak over the social relations of production and their shaping of the combined exploitation of labour and nature” (Burkett (2006), p. 229) he goes too far, in the sense that Sraffian models may be silent on the relation of production but are not ahistorical: they explain what have just happened, and can say nothing about the future.

Nevertheless it is true that it is possible to use Sraffian models in order to capitalize nature, i.e. conflating natural use-value with capital: I agree with Burkett that this is only acceptable if the goal of the model is precisely to criticize such commodification of nature. And I follow Burkett when he thinks that the fight against capitalism is also a fight for a better human-environment relationship, and when he argues that this was Marx position. This position is contrary to the view of Marx of Martinez-Alier for instance: for him Marx was not really interested in environmental considerations, rejecting the theory of Podolinsky for instance (Martinez-Alier and Naredo (1982)). But Burkett rejects this by saying that, if Marx was reluctant to adopt Podolinsky ideas, it was not because he was thinking the labour was the sole source of value but because Podolinsky wanted to link the theory of value with the use of energy, without clearly understanding that in a capitalist economy value is reduced to human socially necessary labour (see also Harribey (2014) and on this point).



from conditions of production is the real source of the environmental problems, as well as the source of the problem of human development. And if we are looking at reproduction of nature and of human society “in a healthy and sustainable way” (Burkett (2006), p. 53), we must change the scale, but also the way we produce. In Burkett terminology,

“capitalism is a social form of human-material production; hence it still has material, use-value requirements. But these requirements are obviously quite minimal compared to the requirements of a healthy and sustainable interchange between economy and nature. This is precisely why it is so crucial to analytically distinguish capitalist reproduction from human-natural reproduction in general” (Burkett (2006), p. 53).

Burkett then also runs counter to James O’Connor’s two contradictions (O’Connor (1994a)), because for him this is the expression of a separation between two problems (distribution of surplus and environmental conflicts) that are actually well linked<sup>57</sup>. It is because workers are separated from the natural conditions of living that they are embedded in a struggle for the appropriation of the surplus and that, at the same time, nature is destroyed and commodified. Then the fight for human development against capitalism development should be carried out together by workers and environmental activists, as it solves both contradiction at the same time. Burkett thus solves the question of the identification of the social actors of environmental conflicts raised by England (1986) and Martinez-Alier (Pellegrini (2012)): all that are fighting capitalism are also the actors of the ecological distribution conflicts.

### 1.2.8 HARRIBEY

Harribey is a Marxist author, not exactly related to ecological economics, but he writes some articles and one book (Harribey (2013)) related to the question of the nature’s value, to the theory of value, and to Sraffa’s theory. About the debate on the value of nature, Harribey makes five proposal (Harribey (2013), p. 184-185):

1. Natural resources are wealth, i.e. a source of use value.
2. They have exchange values (economic values) only after being processed by human labor (there is no price of oil before it is extracted).
3. They do not create exchange values, but they are one of the main component of human wealth and of exchange values.
4. The choice to preserve them is an ethic and political choice, referring to non-economic values, that can not be measured in money terms.

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<sup>57</sup>He also disagrees with James O’Connor’s argument that Marx was not interested in the environmental questions (Burkett (2006), p. 6).

5. The ecological crisis is the result of capitalism tendency of accumulation and appropriation of all sources of wealth.

On Sraffa's theory, Harribey thinks that it is a decisive argument against the neoclassical theory of value and of distribution, as it proves that the result of exchanges alone are not enough to know the prices, the wage and the rate of profit: one of the distribution variable has to be fixed in an exogenous way. The value of capital can not be measured without knowing the result of the surplus distribution. The neoclassical theory thinks that the existence of a market is sufficient to allocate prices: but actually it undervalues the social relations existing in production. Sraffa is also important as he demonstrates the possibility to calculate the physical rate of surplus and the importance of the conflict between wages and profits for the share of this surplus (Harribey (2013), p. 106).

However, for Harribey, Sraffa hides the social relation of production, because he is not talking about the labor value and about capitalist exploitation of human labor (Harribey (2013), p. 98). Harribey's theory of value is the following (Harribey (2013), 107): human labor is socially approved as producing use value when the commodity is sold on the market (thus the equations of production can be written). Then the market and the capitalist competition ensures that the rate of profit is equalized (thus the price of production can be calculated). Finally offer and demand influences prices of production, generating the actual real market prices. The capitalist conditions of production reduce the value of each produced commodity to its substance, human "socially approved" labor (Harribey (2013), p. 114). Thus this theory is a social relationship theory, before being a theory explaining the prices<sup>58</sup>.

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<sup>58</sup>Harribey makes some approximations about Sraffa: first he thinks that the standard commodity (i.e. the commodity solving Ricardo's problem of finding an invariant value when the distribution is changing) is the ultimate result of Sraffa's analysis (Harribey (2013), p. 97). Actually I think, following Sinha (2009), that this founding is a incident result of Sraffa's analysis, whose ultimate goal was to develop an objective price theory: "it was only when the Standard system and the distinction between basics and non-basics had emerged in the course of the present investigation that the above interpretation of Ricardo's theory suggested itself as a natural consequence" (Sraffa (1960), Appendix D). Second he thinks, following Husson Perez (1980), that the fact that prices are those exchange ratios that allows for the repetition of the production process (in Sraffa's terms: "each commodity, which initially was distributed between the industries according to their needs, is found at the end of the year to be entirely concentrated in the hands of its producer. There is a unique set of exchange-values which if adopted by the market restores the original distribution of the products and makes it possible for the process to be repeated", Sraffa (1960), § 1) means that there is an hidden hypothesis that the system should be in a technological stationary state (Harribey (2013), p. 98). But I do not agree on that: Sraffa tries to find prices just looking at physical exchanges during one period of production. He is not looking at what has happened before, and at what will happen after. Thus prices reflect the conditions of production of that period (they are the exchanges ratios that would prevail if one wants to repeat the production) and they will change as soon as a technical change occurs. Sraffa's definition of prices is the only one possible if we do not know the prices before (and at the end of) the period of production. But this definition does not suppose any assumption on the dynamics of the system.

### 1.2.9 MARTINS

Martins (2013) claims that the classical surplus approach of political economy, showing a revival after the works of Sraffa and Sen (1999), is much more valuable to understand environmental problems than neoclassical economics.

The two approaches first differ from each other about their definition of “human well-being”. Well-being is defined in terms of subjective preferences or utilities in neoclassical economics. Well-being increases if the amount of utility delivered by a given amount of consumed goods and services increases: thus well-being is defined *relatively*. If one adopts the view of neoclassical economics, more is always better, which leads directly to the conclusion that “all goods are scarce, since human beings would always want more goods” (Martins (2013))<sup>59</sup>. On the other end, in classical economics and especially in the capability theory developed by Sen, well-being is defined objectively in terms of “objective functionings”, i.e. “what a human being is, or does” (Martins (2013)). There is well-being if there is a certain level of “freedom to achieve” basic human functionings. This freedom to achieve is defined by Sen as a “capability” and looking at someone’s basic capabilities, it is possible to say objectively (without asking him) if he enjoys a basic well-being or not. Thus the central goals of the two theories are really different: neoclassical economics study the allocation of scarce goods according to subjective preferences, where classical economics study how the economic system is able to produce the means of subsistence needed by everybody and, if the economic system is able to produce more, how this “social surplus” is distributed.

The “social surplus” is defined by Martins as the “part [of production] which is not necessary for the reproduction of the existing economic system (such as luxury goods, or further means of production used in order to expand production beyond the existing economic system)”. So the social surplus is composed by net investment and luxury goods. But how to define luxury goods? By the help of the capability approach, as for Martins, the means of subsistence are equivalent to the means needed to fulfill the basic capabilities:

“in order to know which part of production is not necessary for the reproduction of the existing economic system, while allowing for the maintenance of a certain standard of human well-being, we need to know which part of production is necessary for achieving the standard of human well-being we aim at. The capability approach, developed by Sen and Nussbaum, can play a central role here, by defining the level of basic capabilities which are essential for the reproduction of the economy and society under a given, customary, standard of living” (Martins (2013)).

Is the definition of the surplus by Sraffa equivalent to the definition given by Martins? If non-basic goods in Sraffa are equivalent to luxury goods in Martins,

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<sup>59</sup>And then one has to adopt the definition of Robins (1932): “economics is the study of the allocation of scarce resources which have alternative uses” (cited in Martins (2013)).

then the two definitions are the same. But it is possible that some non-basic goods are needed for the subsistence of the workers. Actually this is made possible by Sraffa as, in his work, the wage is entirely given “post-factum”: thus the wage does not appear as the price of labor, but as a distribution variable and labor is thus not seen as a basic good. If the wage were entirely paid “ante-factum”, thus labor would appear as a basic good, and the wage as the price needed for the reproduction of this basic good. In this case, all non-basic goods could safely be considered as luxury goods. Sraffa is well aware of that fact, but nevertheless chooses the first possibility, as a more classic way of representing wage<sup>60</sup>:

“besides the ever-present element of subsistence, [wages] may include a share of the surplus product. In view of this double character of the wage, it would be appropriate, when we come to consider the division of the surplus between capitalists and workers, to separate the two component parts of the wage and regard only the ‘surplus’ part as variable; whereas the goods necessary for the subsistence of the workers would continue to appear ... among the means of production. We shall, nevertheless, ... follow the usual practice of treating the whole of the wage as variable. The drawback of this course is that it involves relegating the necessaries of consumption to the limbo of non-basic products. This is due to their no longer appearing among the means of production on the left-hand side of the equations: so that an improvements in the methods of production of necessaries of life will no longer directly affect the rate of profits and the prices of other products. Necessaries however are essentially basic and if they are prevented from exerting their influence on prices and profits under that label, they must do so in devious ways (e.g. by setting a limit below which the wage cannot fall; a limit which would itself fall with any improvements in the methods 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).

The idea of Martins is that this limit “below which the wage cannot fall” could be express in terms of basic capabilities. This definition of the customary level of wage is of course the result of an institutional arrangement between the social actors. Then what is above this customary level can be defined as a surplus. This surplus is not needed by the system in order to reproduce itself and to provide basic capabilities: his social value is thus really low, unless it is reinvested into productive activities in order to raise the well-being of all society, or redistributed to the poor people without access to the basic

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<sup>60</sup>England England (1986) adds that choosing the second possibility would mean adding a process of production of labor, with consumption goods as inputs. But this process of consumption is not asking for a rate of profit: that is why it is easier to choose the first option.

capabilities. This reinvestment and redistribution could be achieved through taxation of the surplus. Taxation of the surplus, as noted by Ricardo and Sraffa, does not change the price of basic commodities and the rate of profit of the standard system. Thus it does not have an impact on the production and the consumption of those goods that are needed by the system in order to reproduce itself. The same happens to taxation on rents. But there can be a redistribution of the surplus by other means, e.g. “raises in minimum wage, reductions of working hours, or of the retirement age” (Martins (2013)). These are ways to improve the standard level of living without calling for a permanent growth of the economic system<sup>61</sup>.

Permanent growth is actually needed if one is stuck in the neoclassical paradigm. In this paradigm, all goods are scarce since human needs are never satisfied. Thus it is possible to define differential rents for all goods, in the Ricardian way, and to explain prices in terms of an equilibrium between supply and demand. In this paradigm, labor is also scarce: his price depends on the supply and demand for labor. Thus only permanent growth can ensure that wages will grow up (though with the condition that the population level does not grow faster than the economic production). Thus an increase of the standard level of living depends only on growth and taxation would only disrupt the efficient allocation of scarce goods by the market. So for Martins, the whole problem of the neoclassical analysis is its definition of scarcity, which apply to all goods and which is linked with its definition of well-being, i.e. a scarcity which is defined relatively. This vision of a world full of relatively scarce goods is precisely why the neoclassical paradigm is not the good one to analyze absolute scarcity:

“by trivializing the notion of scarcity, arguing that everything is scarce, rather than focusing on the scarcity of natural resources, mainstream (neoclassical) economists divert our attention away from the study of the natural resources which are actually scarce, rather than contributing to a study of sustainable processes of socio-economic reproduction ... Any attempt to achieve a sustainable world must start by abandoning the (neoclassical) belief that human beings are never satisfied with a limited amount of goods” (Martins (2013)).

Thus the classical approach, interested in the reproduction of the system in order to answer objective basic needs and bypass absolute scarcity, is much more compatible with sustainability analysis. This approach also allows for political and ethical considerations to take part in the definition of those basic needs and the protection of nature could enter in the discussion as a valuable ethic point of view. In Martin terms:

“we need a conception where we can define a certain limited standard of human well-being, which enables the reproduction of

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<sup>61</sup>Marx offers another way to increase this standard level of well-being by radically changing both production and distribution.

the economy, society and nature, in a circular process. The capability approach provides a framework within which we can engage in discussions about the standard of living, defined in terms of basic capabilities. And the capability approach is part of an older perspective, which goes back at least to the classical political economists, in which the economy must be seen as a circular process of sustainable reproduction, where the surplus should be used efficiently, in a non-wasteful way” (Martins (2013)).

### 1.3 The third direction: social metabolism and ecological macroeconomics

#### 1.3.1 BAUMGÄRTNER

All production of goods also produces bads: the economic notion which expresses this relation is joint production. This phenomenon is clearly revealed when one looks at production from the point of view of thermodynamics. In the general case, we have the production of low entropy goods from high entropy raw materials, using low entropy energy; but there is always joint production of high entropy wastes. Indeed, the Second Law of Thermodynamics states that all transformations create a positive quantity of entropy: this implies that all transformation processes are irreversible. And it also implies that there is a limit to the substitution of inputs inside the processes of production: we must at least have a raw material with low entropy, usually energy, if we want to create low entropy goods. At last this entails that there will always be some waste to handle, and that a zero-waste society is an utopia. If all three implications are aggregated, we come back to the debate on the limits to economic growth (Meadows et al. (1972)).

Baumgärtner et al. (2001) question the relevance of the joint production concept for the ecological economics field, which looks to get away from the neoclassical paradigm. In the history of economic thought, mainly two scenarios have been considered: the case where all joint products are goods, and the case where at least one joint product is a waste and one is a good. The second scenario seems to relate directly with the concerns of ecological economics. Applications in the case of optimization of industrial production systems (for instance complex bio-refineries process of production, Centi et al. (2011); Sharma et al. (2011); Tay et al. (2011)) can be found. Other applications lies in the understandings of the relation on a more global scale between the economy and its environment (e.g. see Perrings (1987) and O'Connor (1993b) for a study of the possibility for an ever-growing economy to subsist if the environment has only a limited capacity to produce low entropy resources and to absorb high entropy wastes).

Joint production also raises question on a philosophical level: what about the ethics of producers of waste that are not (yet) taken into account by society? Should the company producing the waste be proactive about the question of waste management, or should the company wait that society acknowledges the brute fact of joint production and decides something? This raises the question of risk management and of precautionary principle, in an epistemologic way.

The concept of joint production is a simple one, easily understood by anybody: it is thus a good concept for knowledge mediation in order to raise awareness on environmental concerns. This is a universal concept, which could be applied on different spatial scales – scale of a company, regions, world, etc. – or time scales – as the time scales of goods (production and consumption) and bads (recycling and absorption by the environment) are usually not the same. This is a systemic approach, which encourages to consider at the same time

resources and wastes: “the resource is the mother of the waste” (Baumgärtner et al. (2001)). Joint production concept also allows to go over the classical link between negative externalities and compensation for damages or restoration, by showing the link between goods production and negative externalities – and thus it allows us to reconsider production before having to repair the mistakes. To resume, this concept describes the links between natural systems and human activity, describes human economy, highlights the responsibilities and the limits of human knowledge, and furthermore appears as a clear and easy-to-understand concept (in opposition to the concept of entropy, for instance)<sup>62</sup>.

### 1.3.2 KRATENA

Kratena (2008) produces an Input-Output model in order to calculate the economic impact for human industries of overshooting the Biocapacity. This economic impact is calculated looking at the cost to reduce the Ecological Deficit for each industry. This deficit is the difference between the Ecological Footprint and the Biocapacity of each industry. The Ecological Footprint (or carrying capacity) is defined as the “biologically productive space that would be necessary to supply all resources a nation’s population consumes and to absorb all the wastes that are generated” (Kratena (2008)). The Biocapacity is defined as “the capacity of ecosystems to produce useful biological materials and to absorb waste materials generated by humans, using current management schemes and extraction technologies”<sup>63</sup> and is measured at the national level. Starting from these definitions, Kratena applies Ecological Footprint and Biocapacity concepts at the industrial sectors level and thus defines the Ecological Deficit of each industry.

Then he assumes that, in order to eliminate the Ecological Deficit, each industry needs to rent a land area corresponding to this deficit, and needs to cultivate it in order to make it “biophysically productive” (Kratena (2008)). This cost of renting and of cultivating the additional land rises the price of the goods produced by the polluting industry. Furthermore, Kratena assumes that there is decreasing returns to scale in this additional activity (the coefficients of the I-O matrices are not constant, but depends on the level of the output produced). These decreasing returns lead to the apparition of Ricardian differential rents, as industries with positive ecological deficit have a lower efficiency in production (measured as the quantity of input per unit of output produced) than industries without this Ecological Deficit. The price of commodities in his model is composed of three parts, the cost of producing under the Biocapacity level, the cost of cultivating the additional land if there is overshooting and the Ricardian rent if some industries have an higher overshooting:

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<sup>62</sup>In an other article, Baumgärtner, Faber and Proops deals with the possibility to link capital theory with this view of joint production. Joint production is indeed a concept which originates from thermodynamics laws and thus should be appropriated (or at least understood) by all theories of value. Baumgärtner et al. tries to look if it can fit within the neoclassical theory of capital (Hotelling (1931), Barro and Sala-i Martin (1995)). My view is that this approach of capital cannot fit within the Sraffian framework.

<sup>63</sup>[www.http://www.footprintnetwork.org](http://www.footprintnetwork.org)



$$\mathbf{p} = \bar{\mathbf{v}} [\mathbf{I} - \hat{\mathbf{E}}] [\mathbf{I} - \mathbf{A}]^{-1} + \mathbf{v}^* \hat{\mathbf{E}} [\mathbf{I} - \mathbf{A}^*]^{-1} + \rho \quad (1.73)$$

With  $\mathbf{p}$  the price vector,  $\bar{\mathbf{v}}$  the value added vector for the part of the output in line with Biocapacity (the value added coefficients comprise “labour inputs and different capital input components (depreciation, gross operating surplus) per unit of output”<sup>64</sup> Kratena (2008)),  $\hat{\mathbf{E}}$  the diagonal matrix of the coefficients representing the part of output corresponding to overshooting),  $\mathbf{A}$  the matrix of technical coefficient,  $\mathbf{v}^*$  the value-added vector for the part of output needed to reduce the overshooting,  $\mathbf{A}^*$  the matrix of technical coefficients with decreasing returns to scale, and  $\rho$  the differential rent. Then multiplying the differential rent of all sectors with the vector of quantities produced, Kratena is able to calculate the “Total Ricardian Rent” for the national economy<sup>65</sup>.

### 1.3.3 Subsystem analysis

A subsystem is defined by Sraffa in Appendix A of his book (Sraffa (1960)):

“a system can be subdivided into as many parts as there are commodities in its net product, in such a way that each part forms a smaller self-replacing system the net product of which consists of only one kind of commodity. These parts we shall call ‘sub-systems’”.

<sup>64</sup>This is main difference between the approach of Leontief (1970) followed by Kratena and the approach of Sraffa: in Leontief, the value added coefficient are expressed in money terms, i.e. their prices is known, whereas in Sraffa only quantities are expressed, e.g. quantities of labor (and the wage is not known).

<sup>65</sup>For Kratena, to introduce this decreasing returns to scale is important as it expresses the fact that the environment is a binding constraint to the economic activity. Thus he claims two things: first that, as this additional activity produces natural capital (biophysical production), he is following the “strong sustainability” paradigm. But actually this is wrong: indeed he is not claiming that the natural capital should be substituted by “man-made” capital, but if the natural capital is now been produced by an economic activity, it becomes in effect a intermediary product, i.e. natural capital becomes “man-made” capital. Kratena is thus claiming for a weak sustainability vision, as the environmental overshooting can be reduced to an economic activity. The fact that this activity shows decreasing returns does not help, as it is still a replacement of natural processes by economic processes.

Second Kratena says that, when there is a binding constraint, the non-substitution theorem (Samuelson (1966)) does not hold. But actually this theorem says that with constant coefficients, single production and no exogenous resources except one (e.g. labor), one technique minimizes all prices when the wage is given, and a change in output (or demand) will not change prices. But Kratena models works with non constant coefficients, as he is assuming decreasing returns to scale in the additional activity needed to reduce the Ecological Deficit. Furthermore Pasinetti (1977) already showed that substitution in neoclassical theory means an inverse relation between proportion of two inputs and their relative prices and that such substitution is a phenomenon which is not verified in Sraffa’s type model of production (and thus also in Leontief type model of production): “in a production context with a given technology - with or without joint products - the traditional concept of substitution makes no sense” (Pasinetti (1977)). So arguing that the non-substitution theorem in Kratena’s model does not hold is wrong: with a change of output, prices will change, but this is not due to a phenomenon of substitution.

A subsystem represents then all the quantities needed to produce, directly and indirectly, one specific commodity or a group of several specific commodities. The construction and the analysis of these subsystems have been investigated by Pasinetti (Pasinetti (1973, 1988)) in order to understand the dynamics of a system of production. Alcantara and Padilla (Alcántara and Padilla (2009)) uses this concept to investigate the induced emission of CO<sub>2</sub> of all sectors of an economy due to the production of one specific consumption good: they take as an example the service sector in Spain.

Their model start from the usual physical relation in single production:

$$\mathbf{A}\mathbf{q} + \mathbf{c} = \mathbf{q} \quad (1.74)$$

With  $\mathbf{A}$  the matrix of technical coefficients,  $\mathbf{q}$  the vector of quantities produced,  $\mathbf{c}$  the vector of consumption goods and services produced. Knowing the consumption of the period, the quantities produced are:

$$[\mathbf{I} - \mathbf{A}]^{-1} \mathbf{c} = \mathbf{q} \quad (1.75)$$

Now equation 1.74 can be rewritten as follows:

$$\mathbf{A}[\mathbf{I} - \mathbf{A}]^{-1} \mathbf{c} + \mathbf{c} = \mathbf{q} \quad (1.76)$$

The quantities produced are decomposed into final consumption and intermediary consumption. Each line of the Leontief matrix  $[\mathbf{I} - \mathbf{A}]^{-1}$  expresses the intermediary quantities needed to produce one unit of the related final consumption good: for the sake of simplicity this matrix will be now denoted as matrix  $\mathbf{L} = [\mathbf{I} - \mathbf{A}]^{-1}$ . Then in order to have the quantities produced by a subsystem, it is sufficient to set all the coefficients but one of the final consumption vector to zero:

$$\mathbf{A}\mathbf{L}\mathbf{c}^i + \mathbf{c}^i = \mathbf{q} \quad (1.77)$$

With  $\mathbf{c}^i$  the consumption vector with all components but coefficient  $i$  equal to zero. Then Alcantara and Padilla goes a bit further by decomposing matrix  $\mathbf{A}$  into a diagonal matrix plus a matrix with only zeros on the main diagonal:

$$[\mathbf{A}^D + \mathbf{A}^0] \mathbf{L}\mathbf{c}^i + \mathbf{c}^i = \mathbf{q} \quad (1.78)$$

This system can be further decomposed by separating the lines corresponding to the processes of production of the sector  $i$  (if there are several industries in the sector, there will be several lines in that sector) from the other sectors of production (the  $m$  other industries):

$$\left[ \left( \begin{array}{cc} \mathbf{A}_{mm}^D & 0 \\ 0 & \mathbf{A}_{ii}^D \end{array} \right) + \left( \begin{array}{cc} \mathbf{A}_{mm}^0 & \mathbf{A}_{mi}^0 \\ \mathbf{A}_{im}^0 & \mathbf{A}_{ii}^0 \end{array} \right) \right] \left[ \begin{array}{cc} \mathbf{L}_{mm} & \mathbf{L}_{mi} \\ \mathbf{L}_{im} & \mathbf{L}_{ii} \end{array} \right] \left[ \begin{array}{c} 0 \\ \mathbf{c}^i \end{array} \right] + \left[ \begin{array}{c} 0 \\ \mathbf{c}^i \end{array} \right] = \left[ \begin{array}{c} \mathbf{q}_i^m \\ \mathbf{q}_i^i \end{array} \right] \quad (1.79)$$

This allows to decompose the impact in terms of produced quantities of the consumption of the good  $i$  into five components:

1. The “demand volume component”, represented by the term  $\mathbf{c}^i$ , i.e. the production of the consumption good  $i$ .
2. The “spill over component”, represented by term  $\mathbf{q}_i^m = \mathbf{A}_{mm}^D \mathbf{L}_{mi} \mathbf{c}^i + \mathbf{A}_{mm}^0 \mathbf{L}_{mi} \mathbf{c}^i + \mathbf{A}_{mi}^0 \mathbf{L}_{ii} \mathbf{c}^i$ , i.e. the quantities produced in the other  $m$  sectors in order to enable the production of consumption goods of sector  $i$ .
3. The “feed-back component”, represented by term  $\mathbf{A}_{im}^0 \mathbf{L}_{mi} \mathbf{c}^i$ , i.e. the quantities of the good  $i$  as intermediary consumption in the  $m$  other sectors in order to enable the production of the consumption goods of sector  $i$ .
4. The “own component”, represented by term  $\mathbf{A}_{ii}^D \mathbf{L}_{ii} \mathbf{c}^i$ , i.e. the quantities needed of the own good they produce by each industry of sector  $i$  as an intermediary consumption in order to enable the production of the consumption goods of sector  $i$ .
5. The “intra spill over component”, represented by term  $\mathbf{A}_{ii}^0 \mathbf{L}_{ii} \mathbf{c}^i$ , i.e. the quantities needed of the goods produced by the other industries of sector  $i$  by each industry of sector  $i$  as an intermediary consumption in order to enable the production of the consumption goods of sector  $i$ .

Then by adding a vector  $\mathbf{e}$  representing CO<sub>2</sub> emissions per unit of output in each industry, it is possible to know the emissions due to the production of consumption goods in subsystem  $i$ , and then to decompose such emissions for all five components. It is furthermore possible to know the emissions of the sector  $i$  due to the production of consumption goods in the other  $m$  industries, by rewriting system 1.79 as:

$$\begin{bmatrix} \mathbf{A}_{mm} & \mathbf{A}_{mi} \\ \mathbf{A}_{im} & \mathbf{A}_{ii} \end{bmatrix} \begin{bmatrix} \mathbf{L}_{mm} & \mathbf{L}_{mi} \\ \mathbf{L}_{im} & \mathbf{L}_{ii} \end{bmatrix} \begin{bmatrix} \mathbf{c}^m \\ 0 \end{bmatrix} + \begin{bmatrix} \mathbf{c}^m \\ 0 \end{bmatrix} = \begin{bmatrix} \mathbf{q}_m^m \\ \mathbf{q}_m^i \end{bmatrix} \quad (1.80)$$

Then these emissions are calculated by multiplying vector  $\mathbf{e}$  with the component  $\mathbf{q}_m^i = \mathbf{A}_{im} \mathbf{L}_{mm} \mathbf{c}^m + \mathbf{A}_{ii} \mathbf{L}_{im} \mathbf{c}^m$ .

This analysis of emissions per subsystem is deepened by Butnar and Llop (Butnar and Llop (2011)), who studied the determinants of changes of CO<sub>2</sub> emissions on the subsystem level, through structural decomposition. In order to do this, they define a subsystem of production in the same way than Alcántara and Padilla (2009), but they only decompose it into three components and then multiply each component by their emissions vector ( $\mathbf{e}^i$  for the emissions per unit of output of the subsystem industries,  $\mathbf{e}^m$  for the emissions of the other industries). The components are as follows:

1. The “demand level component”,  $DLC = \mathbf{e}^i \mathbf{c}^i$ , equivalent to the “demand volume component” of Alcantara and Padilla;

2. The “external component”,  $EC = \mathbf{e}^m (\mathbf{A}_{mm}\mathbf{L}_{mi} + \mathbf{A}_{mi}\mathbf{L}_{ii}) \mathbf{c}^i$ , equivalent to the “spill over component” of Alcantara and Padilla;
3. The “internal component”,  $IC = \mathbf{e}^i (\mathbf{A}_{im}\mathbf{L}_{mi} + \mathbf{A}_{ii}\mathbf{L}_{ii}) \mathbf{c}^i$ , equivalent to the addition of the “feed-back”, the “own” and the “intra spill over component” of Alcantara and Padilla;

The total emission due to the production of consumption goods in subsystem  $i$  is thus written as follows:

$$E = DLC + EC + IC \quad (1.81)$$

The starting point of the structural decomposition is to assume that changes in total emission  $E$  is due to changes, at different levels, in the three components:

$$\Delta E = \Delta DLC + \Delta EC + \Delta IC \quad (1.82)$$

Then the changes of emissions in each component can be the result of a change in the emission coefficients (change in the “emission term”,  $ET$ ) or the result of a change in the technical coefficients (“technological term”,  $TT$ ) or finally the result of change in final demand (“demand term”,  $DT$ ). All three determinants can of course change at the time, but the goal of structural decomposition is precisely to understand how each determinant impacts the total emission change. The difficult task with structural decomposition is to understand how determinants are related to each other: for instance, for the demand level component, Butnar and Llop assumes that changes in emission coefficients are independent from changes in final demand. But in the external and the internal components, the changes of emissions are considered to be dependent with the changes of technical coefficients, so that the technological term includes both, whereas changes in demand are assumed to be independent from changes in technology. The structural decomposition of total emission is then:

$$\Delta E = \Delta ET_{DLC} + \Delta DT_{DLC} + \Delta TT_{EC} + \Delta DT_{EC} + \Delta TT_{IC} + \Delta DT_{IC} \quad (1.83)$$

If the assumptions are correct, it is therefore possible to better understand the reasons for a change of the emissions of one subsystem, and thus to better identify which policy will help to reduce those emissions.

#### 1.3.4 KEMP-BENEDICT

Kemp-Benedict (2014) writes an interesting article about the vertically integrated structure of the economy. The goal of this representation is to highlight aggregated markups, on labor on one hand and on rent from the exploitation of natural resources on the other hand.

These aggregated markups are constructed from a three sector economic model with sector 3 extracting natural resources, sector 2 transforming these raw materials into bulk commodities, and sector 1 producing intermediate commodities (used in all sectors) from bulk commodities. The final demand consists of intermediate commodities.

Matrix  $\mathbf{A}$  of input coefficients, vector  $\mathbf{l}$  of labor coefficients and matrix  $\mathbf{B}$  of output coefficients are then represented in this way:

$$\mathbf{A} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & 0 & 0 \\ 0 & a_{32} & 0 \end{pmatrix} \quad (1.84)$$

$$\mathbf{l} = ( l_1 \quad l_2 \quad l_3 ) \quad (1.85)$$

$$\mathbf{B} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (1.86)$$

The system of equation for the physical side is:

$$\mathbf{B}\mathbf{y} = \mathbf{A}\mathbf{y} + \mathbf{d} \quad (1.87)$$

With  $\mathbf{y}$  the activity vector and  $\mathbf{d}$  the final demand vector.

The system of equation for the value side is:

$$\mathbf{p}\mathbf{B} = (\mathbf{p}\mathbf{A} + w\mathbf{l} + \mathbf{r})\mathbf{\Pi} \quad (1.88)$$

With  $\mathbf{p}$  the price vector,  $\mathbf{\Pi}$  the diagonal matrix of markups (equivalent to sector-specific rates of profit),  $w$  the wage (uniform in all sectors) and  $\mathbf{r}$  the vector of rents. Kemp-Benedict assumes that each sector performs mark-up pricing so that they each have a different rate of profit:

$$\mathbf{\Pi} = \begin{pmatrix} 1 + \pi_1 & 0 & 0 \\ 0 & 1 + \pi_2 & 0 \\ 0 & 0 & 1 + \pi_3 \end{pmatrix} \quad (1.89)$$

Furthermore the vector of rents only have one component different from zero, the rent of sector 3:

$$\mathbf{r} = ( 0 \quad 0 \quad r ) \quad (1.90)$$

Knowing the final demand, it is possible to know the level of production in each sector, and the level of employment  $L$ :

$$\mathbf{y} = [\mathbf{B} - \mathbf{A}]^{-1} \mathbf{d} \quad (1.91)$$

$$L = \mathbf{l}\mathbf{y} \quad (1.92)$$

Knowing the wage (uniform in all sectors), the rents on natural resources and the markups in each sector, it is possible to deduce the prices:

$$\mathbf{p} = (w\mathbf{l} + \mathbf{r}) \Pi [\mathbf{B} - \mathbf{A}\Pi]^{-1} \quad (1.93)$$

Then, multiplying final demand with the price vector, it is possible to calculate the GDP of the economy. Indeed we have:

$$GDP = \mathbf{p}\mathbf{d} = (w\mathbf{l} + \mathbf{r}) \Pi [\mathbf{B} - \mathbf{A}\Pi]^{-1} [\mathbf{B} - \mathbf{A}] \mathbf{y} \quad (1.94)$$

And Kemp-Benedict demonstrates that it is possible to represent GDP as :

$$GDP = X_w wL + X_r r y_3 \quad (1.95)$$

With  $X_w$  the aggregated markup on wages and  $X_r$  the aggregated markup on rents, both depending only on technology and markups (independent from prices and levels of activity).

From this last representation of GDP, Kemp-Benedict deduces some observations about taxation of rents, natural resource productivity and resource return on investment (RROI, “given by the ratio of the amount of raw material extracted, divided by the direct and indirect use of that raw material in its extraction” Kemp-Benedict (2014)). One interesting point is that if RROI becomes too low, then, at one point, the markups on wage and rents become infinite and the economy cannot run anymore. He also found that the aggregated markup on rents is higher than the aggregated markup on wages:  $X_r > X_w$  and that the economy-wide mark-ups are larger than sector-specific mark-ups.

About theory of value, Kemp-Benedict approach is a bit unclear. The interesting aspect of his approach is to take into account absolute rent, which is not represented in Sraffa’s system. Kemp-Benedict explains that rents are the price of the exploitation permits. Rent appears in the system of equation as the third distribution variable, along with wage and profit. This representation is possible and expresses the result of an institutional arrangement between rentiers, capitalists and workers. But his theory of price is less convincing. He first explains that price are the result of mark-up pricing (each firm chose the rate of profit they want to earn, and they sell their product at a price equivalent to the cost of production plus their mark-up), but with the exception of firms that produce raw materials, as their prices are “determined by their availability relative to their demand, in marginalist fashion” (Kemp-Benedict (2014)). He justifies this because there is no possible substitution of raw materials in the short term, but in his model, Kemp-Benedict finally chooses to use only mark-ups pricing. Then he explains that it is possible to have different markups for different sectors, but latter he find more convenient to assume a uniform rate of profit. Actually from a Sraffian point of view, in the system of equation described by Kemp-Benedict, all goods are basic and all processes are

interdependent. Thus only a uniform rate of profit is possible, once the wage and the rents are given<sup>66</sup>.

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<sup>66</sup>It is not easy to understand what findings in terms of political economy we could learn looking at aggregated markups. He is trying to express the part of GDP which is based on the use of environmental resource, as he is trying to reveal Daly's "inverted pyramid" (natural resources extraction account for only 5% of the global GDP but actually all production is related to this initial extraction, Daly (1995)). But actually I think he is not revealing the part of GDP related to the extraction of natural resources by doing this, because if there would not be any extraction, then the GDP would be equal to zero. Extracting natural resources is a necessary condition, in his system, to produce economic values. So what he is actually revealing with equation 1.95 is by how much the value of the GDP has increased when a rent on natural resources is added. If there were no rents, the GDP value would be equal to:

$$GDP = X_w wL \quad (1.96)$$

Thus by adding the rent, the GDP increases. But this does not mean that production has increased, and that aggregated mark-up  $X_r$  in equation 1.95 shows the part of production which is created because of the environment. GDP has increased indeed, but just because now someone expects a return on natural resources extraction. Kemp-Benedict does not acknowledge that, and even think that if the labor is made endogenous, we could have a better accounting of the part of the GDP coming from the environment, referring to the energy theory of value developed by Costanza Costanza (1980). But again his approach is interesting when he tries to express absolute rents, and when he develops some physical indicators of the efficiency of the system, through a vertical integration analysis.

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