9. Quantifying Natural Capital: Beyond Monetary Value*

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9.1 INTRODUCTION

In recent years concern over ecological and environmental issues has grown in extension and intensity. The growth of this concern has been accompanied by a shift from a conservationism originally based on ethical and aesthetic considerations, towards more pragmatic positions linked to economic management. In this way, national and international institutions with economic responsibilities have found it necessary to get involved in the issues. Organizations such as the Organization for Economic Cooperation and Development (OECD), the World Bank, the UN Food and Agriculture Organization (FAO) and even the International Monetary Fund (IMF) have come to direct their attention towards these themes in publications and areas of work.

Nevertheless, the widespread concern for the health of the planetary environment together with the declared desire to include ecological–environmental considerations in economic management has still to have a significant impact on the global situation. This can be seen as much in the area of achievements as in viewpoints and theories. As such, a growing tension is produced between admitted global concerns and the lack of equally global approaches and agreements capable of solving them. In effect, the agreed-upon dramatic nature of the issue as seen in documents ranging from the *Manifesto for Survival*, put together by Goldsmith and others in 1972 and signed by a long list of prestigious scientists, the *Global 2000*, commissioned by US President Jimmy Carter and appearing in 1981, to *Our Common Future*, coordinated by Gro Harlem Brundtland in 1987 and including the successive reports by the Club of Rome, all explain how the organizer of the 1992 Rio Summit, Maurice Strong, could present the meeting as 'the last chance to save the planet'. Yet not even this 'last chance' led to global actions capable of efficiently correcting the planetary deterioration that was unanimously recognized. Nor did it establish theoretical schemes capable of guiding actions for the future, new criteria for the reorientation of management and standards for living

and behaviour characteristic of industrial civilization. It seems as though while the number of organizations and amount of literature concerned with these themes has grown, the original ideas have steadily lost their radical nature (in the sense of going straight to the root of the problems), in order to steadily conform to the status quo. To put it in another way, it is as if the rising volume of economic–environmental literature were contributing more to covering up rather than clarifying the conflicting ecological problems and principles which economic management currently presents (Naredo 1998). In summary, it is commonly accepted that the behaviour of industrial civilization points towards a horizon of ecological *unsustainability*, but clear means generally assumed capable of reorienting this behaviour towards *sustainable* ends do not exist.

In my book *La economía en evolución* (1987, republished 1996), I emphasized that this reorientation needed to be based on an *ecointegrated* focus which would open economic thought towards the physical world, beyond monetary value, in order to analyse economic processes from resources (before being assigned value), to wastes (also lacking value). This analysis would be related to that which is habitually practised in monetary terms, but also giving due emphasis to the financial world, whose influence over the formation and distribution of monetary values is ever larger. For some time now I have been applying this focus to the study of very diverse cases[1], demonstrating its potential in aiding different forms of management to consider ecological concerns, leading them to be more viable or *sustainable* than they are at present. Nevertheless, this kind of focus, which emerged strongly in the 1970s during the 'energy crisis' and from concerns over the 'limits of growth', has lately been covered over by the winds of the reaffirmation of 'development', aided by decreases in the price of oil and raw materials. Now, the very idea of growth, emphasizing its lack of physical global viability, is no longer questioned. It has reattained credibility in the search to make it 'sustainable'[2].

The drop in the price of oil and raw materials has moved economic reflection from resources towards wastes, and from physical–energetic processes towards monetary instruments, as if wastes were not the product of the handling of resources, and the sensible application of economic instruments did not demand a thorough knowledge of the physical reality to be managed. Academic literature as well as administrative reports have displayed a curious schizophrenia in this area: much concern over penalizing wastes and the search for economic instruments[3] to offset environmental damage, and a lot of unconcern for the low price of resources as well as the integrated functioning of physical and monetary processes whose expansion generates the aforementioned damage.

However, I have the impression that those of us who have maintained the desire to engage in reflections which integrate physical with monetary flows, and both with natural wealth, find ourselves at the end of a kind of journey across a desert. In recent years, I have happily noted a resurgence in interest in modelling and counting the physical functioning of management systems, accounting for their energy and material needs, the disposal of wastes as well as their territorial implications. The treatment of various problems has led a number of specialists, for simple reasons of coherence, towards the application of more systematic and integrated approaches. On the one side, we have pollution analysis, which at times ends up in preventive positions, referring the 'environmental audits' to an integrated functioning of the processes, taking into consideration the combination of energy and material flows involved. On the other hand, 'life-cycle' analysis (and those of 'total quality'[4] of the product) also cause some to consider in their practice 'ecobalances' referring to the combination of physical flows put into movement. These analyses connect with those which point directly at 'industrial ecology'[5], as reads the title of the book by Ayres and Ayres (1996); towards the analysis of energy and material flows, among which stand out the work linked to the Wuppertal Institute[6]; and also towards the territorial effect (Wackernagel and Rees 1995). These works are contributing towards making more precise and spreading concepts such as 'total material requirement' (as opposed to direct requirements), 'rucksack' and also the 'footprints' of deterioration as a result of the manufacture and use of human products, installations and settlements[7].

On the other hand, from the monetary angle we also see an increased concern for financial and natural wealth aspects. The new System of National Accounts (SNA 93), agreed upon in the United Nations with the consent of the main economic institutions, is a good example of the increased attention paid to these aspects. The SNA 93, which will serve to guide national accounting for the coming years, incorporates financial accounts along with national balance sheets by groups of economic agents, permitting the analysis of aspects which had remained in the shadows.

Nevertheless, in that which concerns natural wealth, the methodological and administrative bases necessary to establish a statistical account of the elements and systems making up that wealth have yet to be attained.[8] We are at the point where, despite the growing concern for conservation of natural wealth, the data available is so extremely incomplete and heterogeneous that they hardly allow us to speak with more precision than did Plato in his dialogues when he referred to 'that which is left to us of the Earth'. Plato was referring to erosion[9] and its consequences; it would have been difficult for him to imagine the damage caused by

the powerful mining interventions and pollutants resulting from the ongoing march of industrial civilization. With this in mind, instead of arguing so much over the uncertain consequences of possible climatic changes, we should be more concerned with the interventions which with certainty effect on a daily basis the land and the natural resources which it contains.

This chapter is an invitation to transcend this 'environmentalism' of the 1980s which has brought us the intellectual schizophrenia mentioned above, that which caused us to treat the 'environment' as one more area to include with others in the administration or academic world; causing us in turn to be concerned with wastes but not resources, with the climate but not the land, to concern ourselves with monetary value but not the underlying physical information. For this it will be necessary to overcome our fragmentary approaches, adopting instead a wider economic approach including within its assessments the totality of natural wealth along with the physical and financial flows upon which current societies are based – from resources to waste, from the 'Third World' to the countries of 'mature' capitalism. This chapter will advance along this road, offering as a framework the results of a recent study that relates the above-mentioned dimensions on a planetary scale (Naredo and Valero 1998). This investigation will provide information about the metabolism of current society and its effects of the planet, in order to propose and later apply a methodology permitting us to quantify the deterioration of the natural wealth linked to the main flow of materials which feed it (that of the rocks and minerals extracted from the earth's crust). It will analyse, in the end, the rules which govern the evolution of the physical costs and monetary values generated throughout the economic process, proposing criteria permitting the correction of the asymmetry existing between them. This is an asymmetry which explains the growing abyss between the Third World and the centres of the industrial world: while the former specialize in extraction and manufacturing processes which are the most physically costly, polluting and economically less valued, the latter specialize in the less physically costly and most economically valued phases of the process, as well as having control over commercial and financial management. This is the keystone of the scarcity of capital in the Third World, over which sits the economic dominance of which it is subject, leading to its ecological degradation.

9.2 THE METABOLISM OF INDUSTRIAL SOCIETY AND ITS PLANETARY EFFECTS

9.2.1 Estimation of the Global Physical Flows Which Are Mobilized by Industrial Society

In the book which serves as the basis of the present chapter (Naredo and Valen 1998), an attempt is made to improve the surprisingly scarce and imprecise evaluations available concerning the use that humankind is making of the air, water, photosynthesis and supplies of rocks and minerals contained in the earth's crust. In the case of products derived from photosynthesis and the extraction of rocks and minerals, direct evaluations were attempted working from available statistics of the activities involved, trying to add precision to global-use estimates which at times are supported solely on per capita imputations. The shortage of reliable data in this area betrays a lack of administrative support in flagrant contradiction to the long-running concern for 'environmental problems' that national and international administrations have trumpeted. Table 9.1 shows the magnitude in tonnage of the extraction of resources upon which, according to our calculations, the planetary economy in 1995 was supported.

One first observation comes into view: the extraction of rocks and minerals from the earth's crust reaches a tonnage which triples that of products derived from photosynthesis. This highlights a radical difference separating the economic behaviour of current civilization with that practised by human beings throughout their history: fundamentally they had lived, along with the other species making up the biosphere, on photosynthesis and its derivatives, while now our economy is based mainly on the extraction of materials from the earth. This change implies an additional burden caused by the fact the extracted materials are first used and then returned to the environment as waste, without concern for returning them to their original condition as resources, with negative consequences for the biosphere.

On the other hand, only the extraction of fossil fuels approximates in tonnage that of the extraction of all derivatives from photosynthesis. Taking into account that the energetic content of fossil fuels per unit of weight is from two to four times that of agricultural production (fishing and forestry products included) we find that human beings use as fossil fuels an amount of energy much greater than that derived from

Table 9.1 Tonnage linked to extraction of biomass and mineral resources, planetary total (in 10^9 mt), 1995

	Products
Agriculture	3.6
Forest resources	6.2
Livestock	0.7
Fishing	0.1
Agrarian total	10.6 + direct losses (17) + indirect losses (37)
Fossil fuels	10.0 Ore (11) + Unproductive (15) = 26
Metallic minerals	1.0 Ore (4) + Unproductive (12) = 16
Non-metallic rocks and minerals	21.0 Ore (22) + Unproductive (3) = 25
Total rocks and minerals	32.0 Ore (37) + Unproductive (30) = 67
Addendum	Water used (10^{12} mt) in 1995
Agriculture	4.1
Other uses	0.7
Total	4.8

Source: Naredo and Valero (1998)

photosynthesis. The energy use leads to an increase in other extractions from the biosphere as well as the earth's crust, to transport them and process them, also forcing the ever more massive utilization of water and air as resources and sinks. We point out here that the quantities of water and air utilized on earth amount to trillions (10^{12}) of metric tons, while the extractions from photosynthesis and the earth's crust amount to billions (10^9) of metric tons. An estimate of the quantity of water utilized is included in the lower part of Table 9.1. At present this quantity approaches half of the annual accessible water flow and, being to a large part returned in a polluted form, invalidates a still higher proportion.

In the processes of extraction, production and handling of materials on a large scale, humankind finds it necessary to move an increasingly higher tonnage of earth and organic materials than that which is used directly, aggravating the deterioration of the environment (in addition to provoked by wastes). Table 9.1 summarizes the estimates of the total movement of materials resulting from agrarian and mining activities. The difference between commercial products obtained and the movement of materials needed to obtain them reaches its apex in the case of metals: the ore and waste in this group amount to ten times the tonnage of commercial metals produced. This ratio is much higher for substances such as gold and copper, whose collection and benefit in addition imply massive handling of water, energy and pollution.

In summary, the mining of rocks and minerals has a more significant impact on the Earth than any other geological agent. Annual movement of earth related to extractive activities now approaches 70 billion metric tons, a figure four or five times that of the estimated tons of sediment moved along annually by all the rivers of the world (some 16.5 billion metric tons), comparable to the vital cycles of carbon and biotic dry materials implied in photosynthesis (we can calculate the 'primary production' – dry weight – on continental lands at 132 billion tons). From there we can see that, with industrial civilization, the earth is being converted more and more into a *huge mine*, as reads the title of the monograph included in one of the reports about 'the world situation' promoted by the World Watch Institute in Washington (Young 1992). All of this justifies the need for a high priority economic treatment of the use our civilization is making of the 'mineral capital' of the Earth, as we propose in Naredo and Valero.

We can see that industrial civilization has made it possible for humans to utilize a level of exosomatic energy much higher than that in the form of food. It is precisely this exosomatic use of energy that has permitted the increase of levels of extraction and the horizontal transport of materials, breaking with the functional schemes of natural ecosystems (where vertical transport predominates) and bringing the well-known problems of pollution (as Margalef (1992), has said, pollution is an illness brought about by this horizontal transport). We emphasize here that forcing, through this exosomatic energy, the collection of products derived from photosynthesis in agriculture, fishing and modern forest exploitation, is leading to the deterioration of the natural resources that had originally made possible the development of photosynthesis. The sustainability of traditional agriculture is explained by taking into account the possibilities of recovery of the local ecosystems, adapting cultivation and exploitation to the reasonable productive possibilities of the land. Modern agriculture, however, is forcing the extractions, through the application of water and fertilizers, separating by this the crops from the possibilities offered by the stable maintenance of the natural resources of the land, causing their progressive deterioration: loss of soil fertility, of biological diversity, lowering of water tables and so on. In this way, after having placed the notion of production within the centre of economic science, industrial civilization is converting the only products that had been traditionally renewable and sustainable (that is, the products of agriculture, fishing and forests) into non-renewable and unsustainable ones (supported by the ever-deteriorating combination of mineral reserves and biotic resources).

The exploitation and use of the biosphere, the earth's crust, the

hydrosphere and the atmosphere has left evident marks of deterioration on the land (reduction of the surface area of forests and other natural ecosystems of great biological diversity and scenic interest, the advance of erosion and loss of vegetable cover, the occupation of land having the highest agronomic quality for extractive or urban–industrial use as well as the construction of infrastructures and so on). The higher the requirements for water, energy and materials obtained from (and dumped back into) the earth, the higher the requirements and effects on the land.[10] Although the analysis of these requirements and effects on the land would be of great interest in the analysis of physical flows which we are attempting, we are obliged to leave it out of this study.[11]

9.2.2 The 'Dematerialization' Which Does Not Arrive

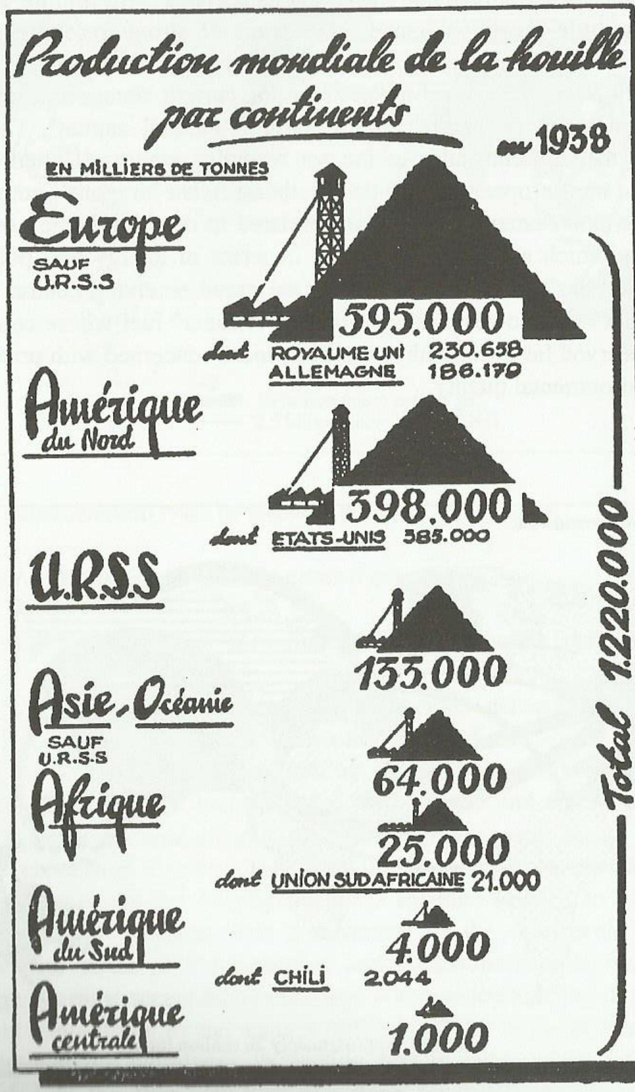
Naredo and Valero include historical series concerning the extraction of substances from the earth's crust, showing the spectacular growth that has occurred over the past 30 or 40 years which gives no indication of slowing down. Efforts to improve the efficiency of the processes have not led to a general reduction of extractions (although they have contributed to moderating the growth of some of these activities), apart from the exceptions of lead and tin, due to technological or normative changes. In short, as the data shows, we cannot speak of a generalized 'dematerialization' in our societies. To the contrary, the total material requirements are increasing even in the most 'advanced' societies, although the direct material needs of these countries may decrease as a result of the tendency to move the first phases of the processes of extraction and treatment of materials outside their borders, together with observed improvements in efficiency in the later processes. Within this process the *local* environment of the wealthy countries has a privileged position at the cost of a *global* deterioration, this global environment being utilized as a source of resources and waste sink. Coinciding with other recent analyses of this issue, we can conclude that at least, '*dematerialization*, in the sense of an absolute reduction in the use of natural resources, is not taking place' (Adriaanse et al. 1997, pg. 2), in the wealthy countries, and less still in the so-called 'emerging economies', or in those more or less euphemistically qualified as 'on the road to development'. All this reinforces the importance of the kind of work we do, because the belief in *dematerialization*, the suggestion that we are undoubtedly advancing towards a kind of 'post-industrial' society less and less dependent on natural resources has favoured a lack of concern for understanding and improving the material functioning of society. In other words, the illusion of *dematerialization*, in ignoring the increases in total material requirements which in fact continue to exist, has helped to eclipse the concerns which could contribute to this very dematerialization actually coming about.

Another concern is that the evolution of the prices of raw materials seen in the last decade has taken away the incentive to save and recycle those resources. In fact, the data contained in Naredo and Valero show that the relative lowering of prices of the majority of raw materials has had the effect of stagnating or reducing the demand for recycled materials, as opposed to the increased interest observed when costs of those raw materials rose during the so-called 'energy crisis'. Thus we see that just at the moment when there is talk of 'dematerialization' and 'sustainable development', reality points in the opposite direction. Not only do the total material requirements continue to increase, but those requirements are supplied by an increase in extractions as well as residues, lowering the incentive towards recycling of the stock of materials in use.

9.2.3 Territorial Inequalities

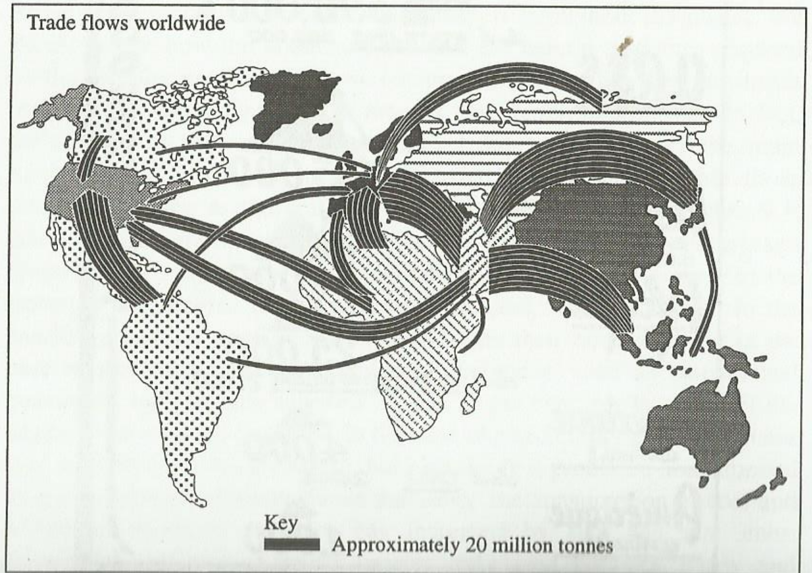
It is important to highlight the unequal use, on a worldwide scale, of extracted materials and energy. This gives rise to an imbalance which explains the high level of horizontal transport throughout the planet. We should notice how the imbalance between the natural resources required by the wealthy nations and those resources found within their territories increased dramatically from the time of the Second World War. In fact, during the era of coal-based capitalism, the exploitation of the main minerals used (coal and iron) was carried out basically within those countries serving as the cradle of the industrial revolution. Figure 9.1, taken from a book about natural resources published half a century ago (Peyret 1944), notes how the principal producers of coal were also the principal consumers. Similarly, only 7 per cent of the iron used in the wealthy countries was imported from outside their borders. Even in the case of the most unequally distributed resources, such as bauxite and petroleum, imports only supplied 21 and 25 per cent, respectively, of the needs of the wealthy countries. In the case of petroleum, the United States was the first consuming country, but also the first producer, and supplied its needs without difficulty. Since that time, the consumption of coal and petroleum in these countries has increased by five and ten times, respectively, causing a much greater imbalance between needs and quantities available within their territories. The same has occurred with the majority of minerals, for which these countries are in general net importers, demonstrating that their economies are maintained by putting into service the rest of the planet, as a source of resources and sink for their wastes. It is here important to distinguish between the case of the

United States and that of Japan and the European Union. The first is a country that contains a huge amount of territory, low population and tremendous supplies of minerals. This, together with the maintenance of



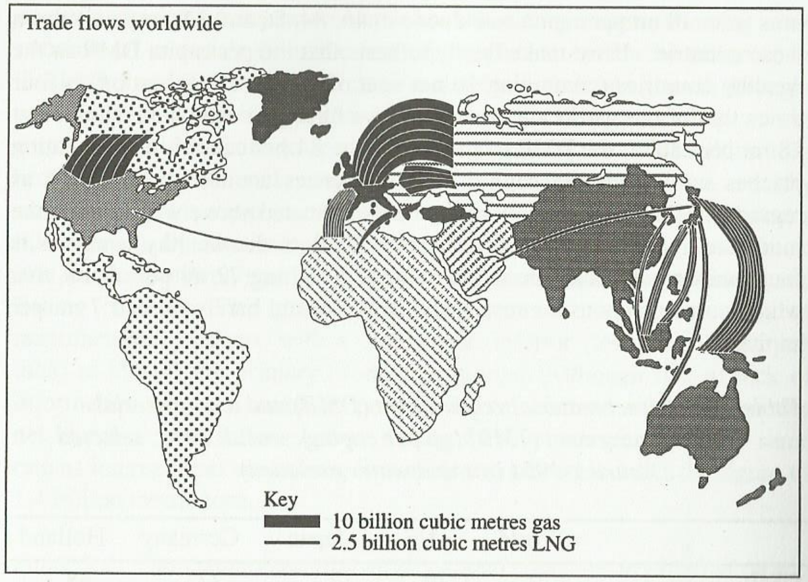
Source: Peyret, H. (1944), The War for Primary Materials, Paris: Publications Universite Francais (PUF)

Figure 9.1 World coal production (1938) an active mining policy, makes for high levels of self-supply, at times even allowing it to be a net exporter of some substances, in spite of its high demands. The opposite occurs with Japan and the European Union, whose much smaller resource endowments together with mining policies providing little incentive, make them areas of strong resource deficit. With these clarifications, the world petroleum and natural gas flow maps (Figures 9.2 and 9.3) reveal much about the current situation in that they reflect the main use centres of the earth's 'mineral capital'. The map referring to petroleum adds to the net receiving centres (United States, Japan and the European Union) the Southeast Asian 'dragons', noting that their economic 'emergency' is not unrelated to the introduction there of industries which are very demanding in terms of energy and pollution. These 'dragons' do not figure among the grand receiving centres of the natural gas map, however, since this is a 'cleaner' fuel whose consumption is reserved for the wealthy countries, more concerned with preserving their environmental quality.



Source: British Petroleum (1996), BP Statistical Review of World Energy

Figure 9.2 Major world trade in oil (1996)



Source: British Petrolem (1996), BP Statistical Review of World Energy

Figure 9.3 Major world trade in natural gas (1996)

9.2.4 The Need for Raw Materials and their Unequal Distribution

Table 9.2 presents the average per capita direct material requirements (DMR) and total material requirements (TMR) of the world, as well as that of the four countries where similar information is available. Worldwide per capita data is the result of dividing biotic and abiotic extracted products (and their total effect in mobilized tonnage) as collected in Table 9.1, by population figures. Data from the four countries comes from a study published by the World Resources Institute (1997), to which we have previously referred. The comparison of the worldwide average figures with those of the countries under consideration is interesting, although we must accept the comparison with caution keeping in mind the different methodologies and sources utilized, as well as the different years of reference (the worldwide evaluation was focused on the year 1995, while that of the four countries was done for 1991). In any case, the imprecision of the data cannot obscure a difference of such magnitude as to clearly reveal an extremely unequal situation. The average DMR of 7 metric tons (mt) per capita worldwide rises to 17 in Japan, to 20 in the US, to 22 in Germany and to 38 in Holland. At the same time the TMR runs from 18 mt per capita worldwide to 46, 84, 86 and 84, respectively in these countries. If we make the hypothesis that the per capita DMR in the wealthy countries (containing 16 per cent of the world population) is four times that of the world average (7 mt) we have just estimated, situated at 28 mt per capita, the DMR of the rest of the 84 per cent of the population reaches only 3 mt per capita. The differences are also pronounced as regards the TMR: if in view of the cases indicated above we maintain the moderate hypothesis that the per capita TMR of the wealthy countries is four times greater than the world average, reaching 72 mt per capita, that which corresponds to the rest of the world would barely exceed 7 mt per capita.

Table 9.2 Direct material requirement (DMR) and total material requirement (TMR) (mt per capita): world, 1995; selected countries, 1991 (air and water excluded)

	World	US	Japan	Germany	Holland
DMR	7	20	17	22	38
TMR	18	84	46	86	84
TMR imported	–	5	25	31	62
DMR national	–	79	21	55	22

Source: World: Our own calculations working from Table 9.1; Countries: World Resources Institute et al. (1997).

Table 9.3 Evolution of world exports in tonnage, 1981–1995 (millions of mt)

	1981	1985	1990	1995*
Agricultural products	479	427	940	1149
Fuels	1666	1499	1896	2341
Extractive industries	563	555	651	887
Manufacturing	415	556	811	1104
Total	3123	3037	4298	5481

Note: *Estimation based on annual growth figures for volume per group of commodities.

Source: World: Our own calculations working from Table 9.1; Countries: World Resources Institute et al. (1997).

In Naredo and Valero, we were able to verify, making use of international commercial statistics[12], that the group of wealthy or 'developed'

countries imports many more metric tons than they export, showing a net entrance of materials from the rest of the planet. As can be observed in Tables 9.3 and 9.4, this net entrance maintained moderate growth throughout the 1980s, reaching 1.136 billion tons in 1990, according to our estimates. This leads us to assume that a quarter of the 4.298 billion tons moved by international commerce in that year went to the wealthy countries. This net entrance was largely made up of fossil fuels (almost a billion tons), by other materials derived from extractive activities (almost two hundred million tons) and on a much lesser scale of agro-forest and fishing products. This group of countries was a net exporter only of manufactured products, with a tonnage far inferior (less than 40 million tons) to that of the primary products imported. Although due to lack of information we were unable to prolong the calculations until 1995, if this net entrance were to have grown during the five-year period at the same rate as international commerce, it would have passed in 1995 the figure of 1.4 billion metric tons.

Table 9.4 Net commercial flow of developed countries in physical terms, 1981 and 1990

	Tonnage (thousands of mt)		
	Exports	Imports	Net
Agricultural products			
1981	64 305	59 876	4 239
1990	71 457	114 219	–42 762
Industrial extract.			
1981	18 592	184 842	–166 249
1990	25 863	208 110	–182 247
Fuels			
1981	33 633	868 793	–835 159
1990	47 951	995 250	–947 298
Manufacturing			
1981	64 048	19 447	44 600
1990	71 218	35 312	35 906
Total balance			
1981	180 568	1 132 958	–952 569
1990	216 490	1 352 891	–1 136 401

Source: World: Our own calculations working from Table 9.1; Countries: World Resources Institute et al. (1997). From 1990, data in tons disappeared from the UN International Trade Directory. As this table was based on this data, it could not be brought up to date.

9.2.5 The Problem of Wastes Is Concentrated in the Wealthy Countries

This enormous net entrance of resources sooner or later ends up being converted into wastes which are rarely the object of recovery or recycling. This makes the accumulation of wastes the primary problem of the 'environmental policy' of these countries; the concern is not so much over the cause (such massive handling of resources brought from all over the world and the damage caused in the countries of origin), but its effects (wastes and environmental deterioration which occurs in the receiving countries). On a NIMBY ('not in my backyard') track, the idea is to get away from the negative effects the wastes have within their own territories, leading to a growing pressure to send them back to the rest of the world. In the case of the burning of fuels, it is the winds that take care of redistributing the wastes through the planetary atmosphere. In that of liquid wastes, it is the water channels which in the end carry them to the common sink of the oceans. As such, the discussions centre rather on solid wastes, particularly on those considered toxic or dangerous. It seems lamentable that a serious statistical control over the emission and transportation of these wastes on a planetary scale does not exist (Greenpeace (1991), promoted a necessarily incomplete inventory of these, later followed by other equally partial or incomplete attempts on the part of some other international organizations). The NIMBY policy rules among the main waste-producing countries; those which, with few exceptions, fall under the qualification of 'the sinister seven' which that ecological organization applied to the seven countries opposing the prohibition of the export of wastes suggested at the Basel Convention in 1989. This polemic over the exportation of wastes arose again on various occasions, including the Rio de Janeiro Summit in 1992, sparking petitions for the ceasing of these activities. Nevertheless, the repetition of these discussions and demands indicates that to prohibit the wealthy countries from exporting wastes to the rest of the planet runs up against the dominant logic: once commerce has put planetary resources at the disposition of the wealthy countries, they now ask that the 'environmental policies' according to the rules of the economic game put planetary dumps at their disposal.

The growing pressure of the wealthy countries to get rid of the wastes they generate by inexpensive and effective means has brought them to consider the possibility of sending the wastes to the bottom of the seas; this is seen as the least problematic ecological and social solution. The large ocean floors can as such constitute the ideal dump, completely in line with the dominant logic of not demanding of the economic agents involved that they assume responsibility for recycling, or at least 'neutralizing', *in situ*, the wastes they generate. As Ramón Margalef[13] has pointed out, it is highly probable that environmental policy will end up regulating the use of these zones as a common dump, in order to legally guarantee, through the payment of certain fees, the right to pollute of the wealthy countries.

9.2.6 The Role of Commerce and Finance in the Acceleration of the Extraction of Resources and the Generation of Wastes

What are the economic mechanisms which grant to certain countries, or more concretely to those 'economic agents' residing in them, sufficient purchasing capacity to use not only planetary resources, but also the planetary dumping grounds? In Naredo and Valero, several chapters are dedicated to analysing and exemplifying, at a micro level as well as that of world commerce, the mechanisms which direct valuation in such a way as to balance in monetary terms the imbalance that commerce globally presents in physical terms. They show socio-institutional factors which provoke a notable asymmetry between the physical cost and the monetary remuneration of the processes benefiting those countries and businesses that specialize in the final phases of management and commercialization. This growing international specialization accentuates the 'North–South' imbalance. To the monetary valuation governed by this asymmetry, the game of the financial system is superimposed, contributing more and more to reinforcing the economic power of the wealthy countries and their 'economic agents', beyond that which merely commercial balances allow. In Naredo and Valero we cannot ignore the financial aspects which are ever more important when studying the processes of economic domination and ecological deterioration observed in the world. What occurs in the financial world contributes to the acceleration of the tendencies leading to social polarization and environmental deterioration. It is senseless to try to correct these tendencies by forgetting how the purchasing capacities are generated and distributed around the world.

In this sense I fear that Margalef (1996, pp. 35–6, Spanish edition) is correct when he writes that 'the lack of success of attempts at connecting in a fruitful way the economic and ecological sciences comes to a large extent from the difficulty, more unconscious than conscious, to reach a common consensus about the definition, not only economic but biological, of this social convention which is money' (and, we would add, the liquid financial assets in general, as well as the capacity of public and private entities to create and benefit by them). Keeping in mind that this 'social convention' gives power, this author makes an analogy between the desire for accumulation and

> The territorial instinct of many animals respected by other members of their species as part of a collective consensus within that species, but sometimes extending to others … they have a lot of interest in the study and regulation of the populations of the implied species … It is clear that money is a convention closely related with the aspects mentioned concerning the generation of individual differences in the use of resources, in the handling capacity of the use of the resources which money affords … all contributing much more to inequality (and environmental deterioration) than to the regulation of natural flows in a considerably humanised world.

Naredo and Valero analyse, among other things, the way in which the equilibrium of the balance of payments among countries is resolved on a planetary scale, necessarily focusing on financial aspects. This is because that which determines how wealthy countries balance their accounts is not the *trade balance*, on which the economics textbooks traditionally focus, or even the *current balance*, but is rather the operations of *short-term capital* which the financial markets work with daily. One conclusion can be clearly inferred from this analysis: the unequal capacity which countries possess for the issuing of liabilities which the current financial system will accept enlarges the inequalities among rich and poor nations. This capacity, which is in direct relation to a country's economic (and political) power, leads to the paradox that the wealthiest and most powerful countries are at the same time the most in debt.[14] It is precisely these countries, and the multinationals located in them, that support their growing purchasing capacity over the world on the credit the world grants to them. This process is supported by the growth of financial assets at a much higher rate than that of physical flows, product aggregates or national incomes. In this way a significant *financial bubble* is produced, the value of which grows at a much higher rate than the increase of 'real' variables, through a process of issuing and revaluing of financial assets which, in general, are not related to the physical substratum which in theory should be supporting them.[15]

Table 9.5 quantifies the mentioned phenomena. One can observe how, over the last three five-year periods, the level of growth of world financial assets reached an average annual rate of 14.2 per cent, twice that of the product aggregate or national income. While in 1982 the value of world financial assets hardly exceeded that of the product aggregate or national income, in 1995 it had almost tripled it. This was evidence of the growing disproportion between the 'real' and financial variables, in which the real variables were rapidly losing significance. Perhaps it would be more important to show, from this perspective, the progressive distancing observed between the contribution of the gross formation of fixed capital (GFFC or gross investment in the National Accounts) to the growth of the supply of physical capital, and the growth of financial assets. This is especially important keeping in mind that economic theory traditionally assumes that these two variables should evolve in a parallel way in the medium term. In short, far from bringing closer their positions, the expansion of financial assets at a rate almost three times that of the GFFC, has led to the latter figure decreasing from 21 per cent of financial assets in 1982, to 11 per cent in 1988, and finally to only 7 per cent in 1995.

Table 9.5 *Evolution of main demographic, economic and financial aggregates on a worldwide scale (billions of dollars)*

	Population (millions)	GNP p.c. ($/inhabitant)	GNP	Exports	Investments (GFFC)	Financial assets[1]
1982	4586	2426	11 130	1752	2911	13 864
1988	5112	3552	18 159	2279	3876	36 512
1995	5666	5003	28 352	4890	5681[2]	77 812
Rate of Var: 1982–95 (%)	1.6	5.7	7.5	8.2	5.3	14.2

Notes:
Addendum: Inhabitable land: 133 million Km^2.
1 Negotiable financial 'derivatives' excluded.
2 1994.

Source: World: Our own calculations working from Table 9.1; Countries: World Resources Institute et al. (1997).

The large discrepancy between the growth of 'real' and financial economic dimensions as seen above led Soddy, already at the beginning of this century, to argue that it was erroneous reasoning to confuse the measure of wealth (money as financial liability) with material wealth and in this way confound the expansion of the debt with the growth of wealth (Soddy 1926).[16] Through money not only have we assigned a financial 'equivalent' to real wealth, but we have left behind the restrictions imposed on the growth of wealth by reasoning in terms of monetary value; without having a physical dimension, wealth can grow without limit. Yet money, as with other financial assets, constitutes a liability for the issuing institution. For that reason, rather than being a sign of wealth, money is converted into 'a symbol of debt' – a debt. Money is a form of community or national debt, possessed by the individual and owed by the community, exchangeable with the demand in wealth by voluntary transfer of another individual who wishes to part with wealth in exchange for money. The value of the total supply of money is not determined by the supply of existing wealth (or by the flow of new production), but rather, in a curious way, by the wealth that individuals think exists but in reality does not: it is what Soddy called 'virtual wealth'.[17] The problem, of course, is that physical wealth lacks the attractive 'virtues' of compound interest, which axiomatically accompanies monetary wealth. Thus, in comparison with the always limited or transitory expansion of physical wealth, we have the exponential growth which characterizes the financial world. One of the fundamental problems arising with the uncontrolled expansion of money or liquid financial assets is, in general, that the debt/wealth relation ends up bankrupt. In effect, the power of business to create money in the wide sense, or to issue financial liabilities which the markets accept facilitating as such its liquidity, is more and more escaping the control of society. This leads to the expansion of financial assets (liabilities) at a rate which increasingly distances them from the supply of available physical wealth, and within this the natural capital whose degradation we see day by day. For example, estimations such as that of the average monetary value of services offered by the ecosystems, realized by Costanza et al. (1997)[18] calculate at 33 trillion (10^{12}) dollars (from 1994), are expected to reduce, not only in relation to the collected GDP of the countries, which grows at an average annual rate of 7.5 per cent, reaching 28 trillion current dollars in 1995, but especially in relation to total planetary financial assets, which as we can see grew at an annual rate of 14 per cent, reaching 78 trillion dollars in the same year (excluding 'derivative' financial products). This implies a growing pressure in purchasing capacity on planetary natural, environmental and land resources, causing the necessity to utilize them with attention only to the cost of extraction or use and not to their recovery. The situation worsens if we take into account that the distribution of natural wealth concentrates more than that of the income generated, and that both tend to worsen and polarize more and more on a planetary scale. In this way the mentioned 'globalization' drags us, as it did in the era of colonial world distribution, towards the predominance of a zero-sum economic game, one in which the gain for some implies the suffering of others. This occurs with the proviso that the tendency towards continued growth of the world financial bubble permits the maintenance of the idea among the players that they are producing generalized enrichment, an idea which remains only while the majority do not care to 'realize' their earnings.

9.3 NATURAL CAPITAL, PRICES, COSTS OF EXTRACTION AND REPLACEMENT COSTS

Within the context that we have just described, economists attempt to solve environmental problems by taxing pollution to remove the incentive to pollute and, with weaker effort, by revaluing natural resources to favour their more efficient use. Yet the partial and out-of-context application of these instruments is not capable of changing the rules of the game which cause both *economic development* and the *ecological deterioration* which we see daily. Synthesizing the deterioration caused in the environment by the handling of resources and wastes, Solow (1991) showed that the *sustainability* objective for an economist must include a revaluing of natural capital that would facilitate its maintenance and even its improvement, by including this natural wealth in the category of *capital*. Let us remember that the notion of *capital* which is habitually employed by economists corresponds only to the *supply of physical capital* which, being produced by humankind in the form of installations, buildings and different infrastructures is capable of being directly valued, either by its production cost (monetary) or by its later costs of replacement. Nevertheless, the extension of said notion of *capital* (capable of being put into monetary terms) to the whole of natural resources and planetary environment brings serious valuational problems. It includes resource flows as well as funds or stocks that by definition are not produced by man, and moreover, interrelate to form very complex structures and systems alongside of which the human being is co-evolving. For this reason, this 1987 Nobel prize-winning author noted that in order to successfully translate the idea of *sustainability* to the universe of standard economics it was necessary to 'value the supply of capital (including "natural capital") with adequate shadow prices', that must be assumed by all. The key to all this is the establishment of social conscience and an institutional framework making operative the revaluing and maintenance of this natural wealth.

Leaving aside for the moment the question of whether the monetary valuation of this natural capital is reasonable, useful and viable, it is worth asking: what exactly are those 'adequate shadow prices' which must be attributed to that natural capital? They are not, of course, the contingent values more or less supported in the 'willingness to pay' of some people: this can inform us more about a status quo to be changed than about 'adequate shadow prices'. We think that such 'adequate' prices cannot arise from merely monetary theoretical reasoning, or from the opinions of a misinformed population. In order to design well the economic instruments having influence over the valuation, it is first necessary to clear up the contents of this natural capital. Here we encounter a theoretical gap which we tried in part to fill in Naredo and Valero, and further divulge in this chapter. This gap arises due to the lack of objective orientation for the ordering, under economic criteria, of material elements and systems making up natural capital, that upon which humankind depends for the carrying out of its manufacturing and industries. Recently, this gap is being more strongly felt, as in the idea put forth by authors such as Daly (1991), El Serafy (1991) and others, that the scarcity of natural capital will become the most limiting factor in economic life. The squandering of natural capital, according to this idea put forth also by Solow, can be avoided by investment in it.[19] The problem is that, while the physical and monetary costs of capital goods produced by humankind can be computed using generally accepted procedures, those of natural capital cannot. As such, the typical calculations of the physical and monetary costs incurred in the economic process are usually incomplete; the process depends upon this natural capital, by taking resources and returning them as waste, which do not enter into the accounts. From there we can see that we must base our propositions on operative theoretical formulations, if we want to avoid the possibility that such good intentions do not end up lost in a kind of wailing wall. Such formulations will permit the clear ordering of the conglomerate of elements and systems falling under the denomination of natural capital; this is the first step towards reasonable procedures which, with or without monetary valuation, will influence the economic calculations guiding decisions.

The critiques of the extension of what is normally called 'capital' to include natural resources and the environment key on two previously mentioned aspects. They are, first: the fact that these resources are not normally identified with monetary values, and second: that they are not normally reproducible by human industry. Hence, it is not operative to measure the ecological *sustainability* of economic systems by the requirement that their natural capital, in (deflated) monetary terms, does not decrease. Confronted with the difficulty of calculating homogeneous series of the monetary aggregate of natural capital, some authors[20] have shown 'the need to apply a pragmatic, alternative approach'. This would be based on following the physical flows on which economic systems are supported, as a more operative instrument in deciding if the functioning of such systems is more or less *sustainable*. In Naredo and Valero we propose the application of a complementary approach to both considerations: that of physical flows and that of natural capital. The proposed approach would allow the calculation, from a reference state, of the physical cost of recovering the mineral resources from the earth's crust, bringing closer the economic treatment of this category of resources to that of reproducible capital. In this way, we believe we are in a position to

propose, for 'mineral capital', if not adequate 'shadow prices', at least some reasonable 'shadow costs', whose general acceptance could lead to the establishment of a more adequate system of prices than that currently in use.

Naredo and Valero offer new criteria with which to transcend a serious obstacle which economic analysis of natural resources confronts. Ordinary economic analysis values the supply of resources which nature offers, paying attention to the monetary costs of extraction (and handling), but not to the demands of recovery, systematically favouring extraction over recovery and recycling (where recovery costs must be paid for). Such procedure leads to scarcity of resources and excess of wastes, keeping in mind that the behaviour model of industrial society distances itself more and more from the model of the *biosphere*, characterized by the closing of material cycles, converting, through solar energy, wastes into resources. Calculating the physical costs in their totality (that is to say, including the recovery costs of natural resources) incurred in the 'productive'[21] processes of industrial society, seems to be a necessary step in economically judging those processes and in redirecting the instruments involved in valuation towards improved global sustainability. The evaluation of the physical costs of recovery of mineral resources would be the first step to making the analogy between natural capital and that made by humankind something more than an empty metaphor. The second part of this chapter develops the theories necessary for attaining these calculations, steering the thermodynamic approaches normally centred on 'energy' towards the world of materials.

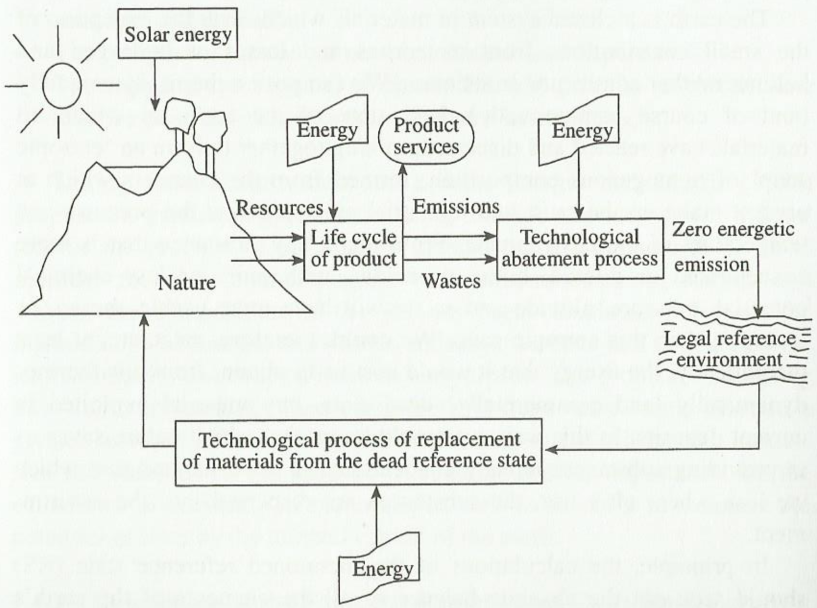
9.4 METHODOLOGY FOR THE CALCULATION OF THE PHYSICAL REPLACEMENT COSTS OF THE EARTH'S MINERAL CAPITAL: FIRST RESULTS

9.4.1 General Premise

With the above-mentioned aspects in mind, we can say that industrial civilization has been and continues to be characterized by the massive use of some substances available in the earth's crust in particular conditions of concentration, structure and tonnage as raw material. The mineral deposits currently being exploited can be considered rarities in the earth's crust, since they have the content percentage of the desired substances and a level of structure higher than the average, which nature has spontaneously decided to configure. Once they are used, these resources often end up dispersed, causing the pollution problems we are all aware of. As has been mentioned, the habitual practices of calculation in economic management do not normally favour recovery and recycling. In addition, seeing these resources as a free gift from nature provides incentive to extract them, not only in comparison with recovery and recycling, but also with other possible renewable substitutes produced from human industry, which would have to be produced and also invoiced (for example, incentives are given not only to replace the mule with the tractor, but also to the use of extracted petroleum instead of ethanol obtained in a renewable way from the biomass).

Taking into account that the conduct described above is pushing the planet Earth towards ever-increasing deterioration[22], the methodology presented below allows for the ordering of minerals in the earth's crust, according to the physical costs we would have to pay in order to obtain them from the dispersed materials which the earth would contain if it had now reached the maximum level of deterioration. A state is assumed, towards which we are now moving, where the current deposits of rocks and minerals would have mixed and reacted with the rest of the components to form an 'entropic soup' in chemical equilibrium. Expressing, in energy units, the physical cost of obtaining the currently available materials from this 'entropic soup', we could arrive at a calculation of the potential (*stock*) contained in the minerals currently composing the earth's crust, that which humankind could exploit and disperse with more or less speed, in comparison with the *stream* (*flow*) of energy by the sun and its renewable derivatives. This presents in clearly quantitative terms the Faustian conflict put forth by the choice between partial efficiency and global sustainability in our society. It shows in other words the election between one economy based on the deterioration of resource *stocks* offered to us by nature, and another economy which appeals to the solar *flow* for the recyclable and improved use of the same resources. We have until now opted for short-term and immediate goals achieved through 'burning in the boiler' determinate *stocks* of resources without noticing the global *unsustainability* such conduct implies. Here we must clarify a quite extended confusion concerning the treatment of material flows linked to economic activity. This confusion arises from the idea that non-renewable resource *stocks* simply cannot be utilized if we adopt a strict interpretation of sustainability. The functioning of the *biosphere* itself contradicts this idea in showing that strict biospheric sustainability has from the beginning been built over the use of the *stock* of materials contained in the earth's crust. The key to this sustainability rests on the fact that, with the help of solar energy, the cycles of materials have been closed, reconverting wastes into resources, something which industrial society does not do. For this reason, the sustainability of an economic

system must be judged not so much by the intensity of use made of *stocks* of non-renewable resources, as by its capacity to close the material cycles through recovery and recycling, with the help of renewable resources. As such, the proposed methodology completes the approaches which analyse the 'life-cycle' of products from the cradle to the grave, reasoning also 'from the grave to the cradle' on the possibility and cost of completely closing material cycles, replacing the natural resources used (see Figure 9.4).



Source: Naredo, J.M. and A. Valero (1999)

Figure 9.4 Life cycle analysis, including replcement of natural resources

9.4.2 Definition of the 'Reference State'

The first step in undertaking the calculation of the replacement cost of the earth's mineral capital has been to define a *reference state* (RS) from which to work. Available literature concerning the composition of the state of maximum entropy towards which the earth is moving is surprisingly scarce. This scarcity contrasts not only with the reiterated concern for the evolution towards deterioration which the earth is following, beginning in antiquity, when the earth was seen as a large organism which would grow old and die like all others. This concern was later seen, a century ago, with the formulation of the law of entropy, leading to thoughts of a 'thermal death'. More recently, we have witnessed renewed worry about the deterioration of natural capital now provoked by industrial civilization. Yet is seems that the faith in Progress has eclipsed until now scientific reflection in this area, today so related with the behaviour of *homo faber*, diverting concerns towards more partial and short-sighted aspects such as the change of the climate.

The earth is a closed system in materials which, with the exception of the small contributions from meteorites and losses of hydrogen and helium, neither admits nor emits mass. We can posit a thermodynamically (and of course commercially) dead state of the earth, in which all materials have reacted and dispersed, mixing together to form an 'entropic soup' of homogenous composition, formed from the elements which at present make up the crust and terrestrial atmosphere at the pressure and temperature of the environment. From there, any substance that is more concentrated or diluted, hotter or colder, with more or less chemical potential, pressure, altitude and so on will have more usable energy, or 'exergy', than this entropic soup. We could, therefore, calculate, at least theoretically, the exergy that it would cost us to obtain, from this thermodynamically (and commercially) dead state, any material exploited in current deposits. In this way, we would know that which nature saves us in providing substances already concentrated in deposits, and that which we lose when, after use, the substances are dispersed into the environment.

In principle, the calculations of the mentioned reference state (RS) should seek out the absolute balance of all the elements of the earth's crust, the state at which these would arrive in yielding all their chemical exergy. Ahrendts (1980) has made this calculation. It is important to note, though, that the reference state proposed by Ahrendts is one quite removed from reality, and would require a very long period of time to reach. It is as such not very appropriate if our analysis is to centre on the results of activities produced on a human temporal scale.

Yet if we also abandon the concept of internal equilibrium defining the thermodynamically dead state towards which the earth is tending, we abandon uniqueness, and everything becomes debatable. Theoretically at least, there would be as many entropic soups as authors. This would bring us to the point in which the valuation of the earth's resources in common units of exergy, if one day this criteria is attained, would have to begin

from a dead state agreed upon by international agreement. In any case, this agreement would not be more controversial than many international agreements reached every day. We believe that it is not necessary to abandon the concept of equilibrium, only that it must be applied to a state closer to the present one than that proposed by Ahrendts.

The reference state proposed in Naredo and Valero as a 'thermodynamically (and commercially) dead state', comes closer to the real physical environment, respecting the following properties:

- Although the RS does not totally reach internal equilibrium at the human scale, the substances that compose it have to be highly stable, abundant and probable.
- The composing substances must have maximum dispersion.
- The chemical and physical processes that take place to reach this state must be of a relatively short duration on a human scale.

Taking these circumstances as a base, Szargut and Morris (1986) proposed a methodology for calculating the RS, and although it did not resolve the problem, it sufficiently marked out the boundaries so as to consider the main methodological work accomplished. In Naredo and Valero, the composition of the RS has been calculated following the methodology of Szargut and Morris, although we have had to make up for its inaccuracies and adapt it more to our purpose. The problem of defining this 'thermodynamically (and commercially) dead' state would demand a greater research effort than we have been able to contribute. We emphasize the viability of this kind of calculation and its importance for the economics of recycling of materials, as well as in order to estimate the potential offered by the mineral capital of the earth.

9.4.3 Calculation of the Exergetic Replacement Cost: Some Results

To begin, the thermodynamic or exergy cost of each mineral (metallic minerals) obtained from the RS was established and calculated, reasoning from reversible processes. Within this theoretical calculation two components were distinguished: concentration exergy and reaction exergy (referring to the change in chemical composition from the RS to the mineral in its present state). Together, these two magnitudes yield the total chemical exergy of the mineral.

Calculations were later performed on real processes (subject to irreversibility), also distinguishing between concentration exergy and reaction exergy. In this way the total exergy that, with currently available technology, would have been necessary to create and concentrate mineral resources from the above-defined RS was obtained. Thus, this calculation provides the exergetic replacement cost of resources with available technology.

Given that the theoretic thermodynamic (reversible) processes as well as the real processes (subject to irreversibility) have the same components (those of concentration and reaction), *the exergetic cost of replacement* is calculated in both cases by the sum of the *exergetic cost of concentration* and the real *exergetic cost of reaction*.

The exergetic cost of real reaction, although higher than the minimum value fixed for the theoretical exergy of reaction, is of the same order of magnitude. As is well known, for example, the oxidation of iron is an exothermic process in which energy is released. If real processes were reversible, by investing this energy we could undo the process, that is, obtain iron from its oxide. This is not what happens in reality; invested energy value is higher than the minimum value fixed by thermodynamics. Nevertheless, our technology is such that both values are of the same order of magnitude.

This does not occur in the processes of mixing and separation, which is where the irreversibility of the processes is most pronounced. When salt and sugar are mixed in water, the energy released is practically nil. Their separation, however, is extremely costly. In fact, when this occurs in our daily life, it is more sensible to throw out the mixture than to make the effort to separate it. The order of magnitude of the energy released in mixing (concentration exergy), and that of the real energy spent for separation (exergetic cost of concentration) are quite distinct. Despite this their tendency is the same.

Table 9.6 shows the comparison between the theoretical and real exergy necessary to *concentrate* certain substances from the standards of concentration in which one can find the mineral in mines up to commercial standards. The data were taken from concentration processes which take place in concrete mineral exploitations. Parameter K indicates the ratio in which the real cost multiplies the theoretical. Note the large dispersion in the values of K among the analysed substances (running from 17 to 25 for iron, to 2566 for tin). This indicates the usefulness of collecting more data about the real physical costs of concentration, which as can be seen differs notably from the theoretical minimum provided by thermodynamic calculations. In the best of cases, for the average of the metallic substances under consideration, real energy necessary for the concentration of mineral wealth in reserves is between 21 and 52 times higher than that calculated thermodynamically. In Naredo and Valero, we estimate that if we were to use and disperse the current base of reserves of the five substances appearing in Table 9.6, a theoretical energy equivalent

to that of all petroleum extracted in 1995 would be necessary to recover those reserves, reasoning from thermodynamically reversible processes. We can see that in working with real processes, many times this quantity would be necessary. This leads us to conclude that the cost which nature saves us in offering deposits with substances in very particular conditions of concentration and structure, as well as the future cost arising from current extraction and dispersal of minerals of the earth's crust are far from negligible. A more profound analysis of these costs is a necessary condition for being able to talk knowingly of the *sustainability* of industrial society or of the consequences on future generations which the current deterioration of the earth's mineral capital will have.

Table 9.6 Calculation of the real and theoretical costs of concentrating certain substances from mine concentration to commercial standard*

Resource	Mine content (%)	Commercial standard (%)	Real energy (KJ/kg)	Theoretic exergy (KJ/kg)	K
Zinc	5.0	50	7.418–9130	87.3	85–105
Copper	0.5	20	17.118–28.530	143.9	119–198
Tin	0.05	60	380.020	148.1	2.566
Iron	30.00	55	456–685	26.9	17–25
Lead	3.00	65	9130–11.412	36.8	248–310

Note: * In reversible conditions.

Source: World: Our own calculations working from Table 9.1; Countries: World Resources Institute et al. (1997).

Table 9.7 offers some of the clearest results which can be arrived at using the analytical tool developed in Naredo and Valero. This chart shows the concentration cost per ton of each of the minerals under consideration, from the RS, in that part which nature saves us (in offering these substances already concentrated in mines), and that part which arises from industrial processes (until obtaining one ton of metal). Results are given in kilograms of oil equivalent[23] (koe) per ton (t) of metal. It can be seen that, for example, for each ton of tin dispersed, a minimum of seven tons of petroleum would be needed to newly concentrate it at the level in which it is found in the mine. Somewhat more than half a ton would be necessary in the case of copper or lead and so on. We can estimate in this way the percentage of concentration energy that nature saves us for each of the five substances: taking into account the estimated reserves for each substance, we can conclude that nature saves us at least 62 per cent of the exergy we would have to spend in concentrating the substances to the point of obtaining metal. It is evident that, as the substances contained in the richest mines are extracted and dispersed, human industry will increasingly have to make up for the concentrating function of nature, with industrial processes (in column 2) rising in importance compared with contributions from nature (column 1).[24] The handling of information such as this can be seen as essential if we want to change the merely extractive mentality of our civilization for one which works towards closing the material cycle, reconverting wastes into resources and mitigating in this way the degradation to which we daily subject our natural heritage.

Table 9.7 *Exergetic concentration cost contributed by nature and by industry in order to obtain a ton of metal from the reference state (dead environment) (kilograms of oil equivalent /metric ton of metal)*

Resource	Concentration in the reference state (per cent)	Mine content *(per cent)*	Real exergetic concentration cost contributed by nature (1) *koe/mt(metal)*	Real exergetic concentration cost contributed by industry (2) *koe/mt(metal)*	Total real exergetic concentration cost of the metal (3)=(1)+(2) *koe/mt(metal)*
Zinc	0.0072	5.0	504–620	406–500	910–1.120
Copper	0.0055	0.5	499–832	634–1389	1.133–2.221
Tin	0.0002	0.05	7.059	11640	18.699
Iron	5.5850	30.00	30–45	15–22	45–67
Lead	0.0016	3.00	535–668	609–762	1.144–1.430
Total			35–52	22–32	57–84

Source: World: Our own calculations working from Table 9.1; Countries: World Resources Institute et al. (1997).

We could proceed in a similar way in order to calculate such a way by *the exergetic cost of reaction*, arriving finally at the *total exergetic replacement cost*. In order to correctly obtain the *exergetic cost of replacement*, real energy data concerning industrial chemical and metallurgical processes as well as separation processes will have to be available, as this is handled in Life Cycle Analysis.

9.4.4 Calculation of the Potential of the Earth's Mineral Capital

Appealing to the methodology that we have just applied to certain minerals, we could extend the calculation of exergetic cost of concentration to the combination of mineral resources contained in the earth's crust. For this we would have to define the way in which each substance is currently distributed in the earth, relating the levels of concentration and the tonnage of the minerals contained therein. Experience indicates that the relation between the percent of concentration (which we can represent in the axis of the ordinates) and the tonnage (in that of the abscissas) has a negative slope and, generally, is an exponential function, convex towards the origin of the coordinates. The slope varies according to the particular situation of each concrete substance. Iron exemplifies the case of very abundant and well-distributed substances, with a good part of the tonnage distributed in average concentrations. However, in rarer and more poorly distributed substances such as mercury, gold or petroleum, the tonnage is heavily concentrated in a few deposits. It is not possible here to base the construction of these kinds of curves on empirical information: to model the relation between commercial ratios and tonnage for the main substances of the earth being exploited, constitutes a further project for the completion of the application of the proposed method. This task has importance in breaking the gap between geological and mining research, a gap which makes the modelling and classification of deposits by grades of physical and monetary cost of extraction difficult. Nevertheless, the first steps have been taken: a methodology of this type has already been designed and applied to deposits of tin and wolfram, demonstrating the viability of this approach (Ortiz 1993)[25]. Once the presence of the substances of the earth's crust is modelled, we can apply the above-explained methodology of calculating the physical cost of replacement of said available substances and, by way of aggregation, quantify in units of energy the physical cost saved by their extraction, avoiding the need to concentrate them before they are extracted.

The proposed methodology has permitted a qualitative leap in those analyses which, from the angle of global sustainability, have been applied to the use of mineral capital in current society, correcting some of the most common mistakes arising from fragmentary approaches. It is now not a case of discussing whether or not the reserves of exploited minerals are running out by a certain date if we continue certain levels of extraction. It is rather the integration of micro analysis of deposits and concrete minerals, at the level of maximum aggregation, and the whole of the earth's crust, in their state of maximum degeneration (the previously defined RS) towards which they are moving. As such, it is not the substances of the minerals extracted from deposits which are running out, but rather the exergy of concentration and reaction of the substances from these minerals. In summary, this methodology would permit us to respond, finally with data in hand, to the concern formulated by Plato ages ago, a worry about that which *is left to us of the earth*, at least as regards mineral capital. Quantifying the replacement of this capital in terms of physical cost is the first step in being able to rationalize its management and quantify the *social costs*[26] resulting from the private use being made of it.

9.5 TOWARDS AN OPEN AND TRANSDISCIPLINARY ECONOMICS

The methodology presented above responds to a concern expressed by Georgescu-Roegen when he pointed out that the limitations or scarcities of our physical environment were about to arise more strongly on the side of materials than that of energy. This takes into consideration the limited stocks of materials contained in the earth, contrasted with the continuous *flow of energy* which the sun daily sends to us, to which is also added the fact that it is much easier to convert materials into energy than to convert energy into materials. This concern led him to formulate what he called the 'fourth law of thermodynamics', which extended the second, the *law of entropy* to the area of materials (Georgescu-Roegen 1977a, 1977b and 1982), with the desire to close the door through which the thinking of certain economists 'liberated' the economic process 'from the quantitative limitations imposed by the character of the earth's crust'.[27] Even an economist as sensitive to ecological problems as Kenneth Boulding expressed the belief that 'fortunately, there is no law of entropy growth for materials' (Boulding 1966)[28], which lead some to affirm that 'the idea of a possible exhaustion of matter is ridiculous. The entire planet is composed of minerals' (Brooks and Andrews 1974).[29] Emphasized here is the existence of the first principle, that of conservation, at the same time that the relevance of the second, that of entropy, is dodged. Yet it is precisely from the principle of entropy that the problems of scarcity in the physical world are derived. We must not confuse the existence of materials in general with the existence of available materials. The methodological developments we have just presented clarify this issue by applying the mentioned law of entropy to the area of materials, without the need to fall back on the 'fourth law' formulated by Georgescu-Roegen (revealed here as a consequence of the second, as we have previously suggested).[30] The methodology and first results of its previously

presented application advance along the indicated lines of research, setting objective bases for judging the different processes and agreeing upon possible changes. From these bases, both economic and institutional means capable of modifying the monetary results of the processes as well as information about their physical implications capable of altering the preferences and behaviour of the population can be developed.

In other words, the purpose of Naredo and Valero is not to practise monetary valuation of natural capital, but to offer physical support points to make possible a reliable application of the economic instruments which bear on this valuation. This gives new possibilities for linking economic valuation in an instrumental mode to analyses of the physical world which is the object of valuation, carried out through the natural sciences. The information on the physical replacement costs of the mineral substances which make up natural capital, as well as the evolution of the physical cost and monetary valuation in production processes (keeping in mind the 'rucksack' of ecological deterioration carried by each product) is a condition *sine qua non* for modifying current tendencies and the modes of valuation that support them.

From this perspective, the valuation takes on a dynamic and instrumental dimension: changing the economic status quo leading to ecological degradation presumes a modification of the bases upon which current valuation is practised, redirecting the mental and socio-institutional framework which has produced it with new information and criteria. We cannot wait for this reorganization to arise from the mere area of economic values. Rather, it must have available solid quantitative support in reference to the physical world in order to establish links between the partial and socially conditioned coherence of ordinary economic calculation which guides management, and the other more global and objective calculation, which, from the natural sciences, informs us about the physical environment in which said management unfolds. This holds special importance in the case of mineral capital in relation to which, not being produced for sale or use, being resource *stocks* and not 'product' *flows*, we cannot expect that the simple game of supply and demand is going to solve the problems arising in their management.

After presenting the method for calculating the replacement costs of mineral substances contained in the earth's crust and illustrating with some results its application, Naredo and Valero continue analysing the combined change of physical costs and monetary valuation operating throughout the economic process, abstracting the rules which govern its combined behaviour. For this a multidimensional approach is applied which accepts that the same economic process can be read in different ways, through different focuses, subject to different axioms, working with different magnitudes and which, for all this, ends up producing not only different numerical results, but results expressed in distinct and irreconcilable units (although it is possible and would be interesting to analyse their combined evolution throughout the processes).

Naredo and Valero clarify these issues, relating the concerns and approaches of ordinary economics of value with those of the 'economy of physics', that is to say, thermodynamics. This clarification is essential in overcoming the confusion which infects economic reasoning in this field, rendering it incapable of tackling the antinomy between *economic development* and *ecological degradation*. Basic questions such as whether it is legitimate for a *sustainable* economy to use non-renewable resources, whether or not the law of entropy governs materials, or whether it is necessary to formulate a new law of thermodynamics extended to this area, should be clearly responded to by the scientific communities concerned with the ecological problems of our times. Such formulations are of immediate practical importance. For example, when asked if, in his opinion, the material transformations involved in economic activity are limited by the law of entropy, Solow responded by recognizing that 'there is no doubt that everything is subject to the law of entropy, but – specifying that – this is not of immediate practical importance in modeling that which is, in the last word, a short instance of time in a small corner of the universe' (Daly 1997, p. 268).[31]

The closing of economic reasoning by unidimensional approaches, whether coming from the universe of pecuniary values, that of standard economics, or from the world of energy, that of thermodynamics, increases the current confusion. It is today more important to highlight the particularity of each approach along with the asymmetries and divergences which can arise from their analyses, than to force unclear and non-operative commitments such as making *development sustainable* while trying to define and meet this goal in the confined area of monetary values, by happily applying prices to the endless number of elements and systems making up the so-called natural capital.

The mentioned confusion surfaces largely from the fact that everyone speaks of the economic system or process, but some approach it from an analytic instrument of economic value, from standard economics, while others arrive from the physical point of view of thermodynamics. It is the more or less veiled assumption among economists, that the standard economic focus is capable of embracing on its own all management problems, which explains their reticence to admit the existence of other competing approaches – interfering, limiting or correcting the assumed universality of their conclusions. Without this assumption, it is frankly difficult to understand the effort of authors such as those previously cited

to minimize and even negate the importance of the law of entropy on the processes related to economic management, when they are aware that it explains the unfolding of phenomena in the physical world in all corners of the universe. Without this assumption, the fact is also incomprehensible that some economists find themselves with the obligation to introduce 'energy' or 'natural resources' in the aggregate[32] production function. These are introduced as a response to the critiques which question the explanatory value of their approaches. The desire to maintain intact the explanatory monopoly of their approaches induces these authors to complete them in this way at the cost of tarnishing their very coherence. It is quite problematic to bring reasoning on these 'external' aspects to the conceptual structure of standard economics without modifying the axiomatic which informs it. When problems that are difficult to fit into a conceptual scheme come up, it is normal that situations fertile in ambiguities and unclear compromises are generated. This is what occurred when Tycho Brahe's eclectic system, postulating that the planets revolved around the sun and the sun around the Earth, substituted for decades that of Ptolemy, opening the road towards the acceptance of the new cosmology of Copernicus, Kepler and Galileo which today is also put into perspective. In the case before us, that which is in question is whether, in order to solve new 'environmental' concerns, economic thinking should continue revolving around the nucleus of mercantile values, or if, on the contrary, the centre of reflection should move towards the conditioning aspects of the physical and institutional universe (analysed by disciplines working from different presuppositions) which surround it. It is a matter of recognizing that, in this crossroads of knowledge which management requires, there is not a unique and immutable *system* of reasoning capable of explaining all, but rather a crossroads of *systems*. This demands the movement of economic thinking from *the economic system* towards *an economics of systems*.

In the area of physics, since the monopoly of knowledge that in its day exerted the *world system* thought up by Newton was broken, it makes no sense to imagine that practitioners of classic mechanics would attempt to find a way to make their system *the one* which is the unique guide for the investigation of astral as well as ultramicroscopic journeys, or situations of irreversibility, discontinuity, non-linear, of permanent disequilibrium and so on – all characteristic of life, upon which other branches of physics reason through different axioms. If the scientific community to a large degree now accepts the possibility and the convenience of utilizing distinct systems of reasoning to analyse the physical world, it should be all the more accepted for the world of economic management. Today it makes no sense that practitioners of classical mechanics feel embarrassed about not taking into consideration the second principle of thermodynamics, attempting to take away the importance it has for analysing phenomena of daily life, or naively seeking a way of incorporating it into a system which by definition excludes it. In the same way, economists would not need to feel embarrassed that their reasoning about value does not include the principle of entropy, if their discipline had reached a grade of maturity comparable to that of physics. On the contrary, economists should highlight that which differentiates their analysis; they study the revaluation (the 'added value') accompanying qualitative changes with a utilitarian finality that constitutes the reason for the so-called processes of production. Thermodynamics is incapable of appreciating such changes in economic value. Physicists need not feel embarrassed. In its turn, thermodynamics works to directly register the physical losses and costs of processes which standard economics can only partially or indirectly appreciate, only when they are objects of monetary valuation. In conclusion, reflections on exchange value in standard economics and those of physical cost in thermodynamics do not substitute for, but rather complement, each other: in our work we have maintained both, as two parallel readings of different aspects of the economic process, both of which should complete our knowledge of that process as well as our ability to reorient it towards a more globally economical direction.

The proposed methodologies and theoretical constructions contained in Naredo and Valero are accompanied by applications at different levels of aggregation. After pointing out that the generation of 'added' values characteristic of economic processes rests on a deep asymmetry between changes in physical cost and monetary valuation, this general formulation is illustrated with the analysis of various processes, connecting with microeconomic levels concerning 'industrial ecology' and the 'eco-balances' of installations and processes, as well as about 'total quality', the 'life-cycle' and 'rucksacks' of the products. The combined treatment of physical flows and monetary values also extends, as we have indicated, to the analysis of international trade, seeing how the cited asymmetry has territorial effects. The processes of extraction and the first phases of manufacturing geographically distance themselves from the main centres of use, accentuating the economic and territorial imbalances known to all. Such imbalances are reflected in the 'North–South' conflict, and in a more general sense can be observed between the centres of capital and product accumulation and the areas of extraction and dumping.

What we have presented offers an objective informative framework useful in examining and reviewing the asymmetry currently observed throughout the economic process: between the physical replacement costs of natural resources and their derivatives, and the monetary valuation of

which they are the object. It provides information as well about the mechanisms involved in the generation and distribution of buying capacity around the world, aspects which condition the valuing processes. Such processes are at once the source of environmental degradation and social inequality, and are reflected in conflicts such as those previously mentioned. An internationally recognized framework such as the one indicated would constitute a solid base of support towards achieving ethical and institutional changes, changes necessary for directing the processes of valuation and management criteria towards the achievement of a more sustainable society of solidarity.

NOTES

* Original: Spanish.

1 From among these applications, it is worth citing: Naredo and Gaviria (eds) (1978); Naredo and Campos (1980); Naredo and Frías (1988); Naredo and Gascó (1990, 1997); Lopez-Gálvez and Naredo (1996); Naredo (1996).

2 The economic–environmental literature has shown more concern for this 'squaring of the circle'; that is the achievement of 'sustainable development', than it has for asserting the physical variables which inform us whether the global sustainability of economic systems and processes is improving or worsening.

3 In the prologue to the 2nd edition of my book *La economía en evolución*, I highlight the 'instrumental deviation' that distances more and more academic economics from the problems of the world in which we live, a 'deviation' which also affects so-called 'environmental economics'.

4 Taguchi et al. (1988); and Arimany (1992).

5 Concerning the convergence of these lines of work; see Allend and Rosselot (1994).

6 As a synthesis of these approaches it is worth noting the publication of Adriaanse et al. (1997). Also worthy of special interest along these lines is the study by Fischer-Kowalski and Haberl (1997).

7 The idea of the 'ecological rucksack' appears basically linked to Friedrich Schmidt-Bleek, director of the Department of Material Flows and Structural Change of the Wuppertal Institute in Germany. The idea of the 'ecological footprint' is linked to Wackernagel and Rees of the University of British Columbia in Vancouver, Canada, especially from their previously cited book.

8 The discussion about ways to approach the 'environmental problematic' that took place during the development of SNA 93 did not lead to any consensus over proposals to alter the aggregates in order to obtain a 'green product' or develop alternative macro indicators. The consensus achieved served only to make a connected proposal of SNA 93, with accounting systems for natural or environmental resources developed through satellite calculations. This compromise proposal was reflected in the UN manual titled *Integrated Environmental and Economic Accounting*, published in 1993, the approaches of which are so generic as to give a merely orienting character as opposed to an operative manual detailing the way in which such accounting is to be done. In this sense only isolated and heterogeneous experiences taking place in specific countries, which some organizations (EUROSTAT, OECD and so on) have tried to coordinate, are available.

9 'That which remains, compared to that which existed, Plato said, is like the skeleton of a sick man, in the sense that all the large and soft earth has been consumed, and only the naked bones remain' (Glacken 1967, p. 139).

10 For example, in the case of the region of Madrid it has been shown that between 1957 and 1980, the total land requirements per inhabitant (excluding land for agricultural use) had doubled at the same time that energy, water and material demands had risen. The increased occupation of land per inhabitant is basically due to an increase in second homes and to indirect uses (reservoirs, landfills, extractive activities, roads and so on). In 1957 these indirect uses took only 10 per cent of the land in the Madrid region occupied for non-agrarian ends, while by 1980 it came to represent 32 per cent. That is to say, the new settlement model showed itself to be a much bigger consumer of land than the old one, since every two hectares of direct urban occupation required another for indirect occupation (Data taken from Garcia Zaldívar et al. 1983). In this way, each model of physical flow utilization leaves a different territorial footprint.

11 The interested reader can find ideas developed along this line in the previously cited work of Wackernagel and Rees (1995).

12 Once more the mentioned schizophrenia surprises: the overdose of figures in dollars contained in international commerce statistics is accompanied by a growing paucity of figures in physical units. For example, starting from the 1990 International Trade Statistical Yearbook; the UN omitted the collection of data in metric tons that it had previously included.

13 Margalef (1998b). Concerning the advantages and inconveniences of using the deep ocean floors as dumps, see (1998a).

14 This circumstance was already reflected upon by Quesnay, who in the seventh observation of his Tableau of 1758 argued in this way: 'the poor countries require a larger intervention of money in trade, since in those countries the mode of payment is usually cash, as no one can confide in the promises of just anyone. But in the wealthy countries there are many men known for their fortune whose written promise is accepted as a safe guarantee due to their wealth. In this way, all important sales are done on credit, that is to say, by means of receipts which replace money, considerably facilitating trade'.(Quesnay 1758, p. 78).

15 The lack of information about the composition and distribution of the property of the world's wealth is surprising, as well as its relation to financial assets. It would be important, for example, in addition to showing in what way the simple revaluing of assets or issuing of new ones contributes to the expansion of world financial assets, to clarify the level at which the value of the new assets issued is based on the simple titling of pre-existing wealth that was the property of physical persons, administrations or other entities absorbed by the corporations which bring out the new titles to sell in financial markets. To this we can add the need to clarify also the differing relation which the new 'derivative' financial instruments maintain with real assets and ordinary finances. We hope that the new internationally agreed upon National Account System (NAS 93), in including at the same time financial accounts and those of natural wealth, will allow the illumination of these very important aspects in order to interpret the evolution and behaviour of the world economy.

16 A synthetic version of the contributions of Soddy in this respect can be found in the selection of texts edited by Martínez-Allier (1995). Also containing an abundance of related material is the book by Daly and Cobb (1989). A reassessment of Soddy's proposals appears in the epilogue to the second edition. The Spanish version of this epilogue has the title: 'Dinero, Deuda y Riqueza Virtual', *Ecologia Politica*, **9**: 51–75.

17 Daly and Cobb (1989, p. 61).

18 Also published in *Ecological Economics*, **25** (1998), together with critical articles by other authors. In an epilogue included in this issue, Costanza and the other authors of the evaluation, recognize having erred in taking as a point of comparison the planetary GDP from ten years ago only as 18 trillion dollars. It is surprising that such a large error could go unnoticed, not only in being published in such a prestigious journal such as *Nature*, but because of its issuance throughout the world press. This is a sign of the ambiguity arising from such exercises in valuation, which imperceptibly pay insufficient attention to other sums which should be an obligatory point of comparison. It also shows that collective reasoning on a planetary scale, using an economic instrument which loses much of its sense at this level, does not habitually show the asymmetries so evident in its comparison with the physical world, as inferred from the growth figures mentioned above.

19 As such, 'Investing in natural capital. The ecological economics approach to sustainability' was the motto of the Conference of the International Society for Ecological Economics, held in Stockholm in 1992.

20 Hinterberger et al. (1997). Along the same lines, see Naredo and Rueda (1996).

21 We place 'productive' in quotes to emphasize the paradox arising from the fact that economic science adopted the term 'production' at that point when economic activity began to rely on the simple extraction, handling and deterioration of mineral supplies in the earth's crust, distancing itself at that point from production derived from photosynthesis.

22 Directly, by dispersion of 'mineral capital' and environmental pollution, and indirectly, in permitting the ever-greater extractions of photosynthesis and massive horizontal transport of materials. With this, the movement of earth occasioned by construction of buildings and infrastructures, erosion and pollution of soil and water, loss of biological diversity and so on.

23 We have chosen petroleum to express this energy cost because the achievements of industrial civilization rest to a great extent on the use of exergy from petroleum and other fossil fuels without concern for recovering them. For this reason, Naredo and Valero contains an appendix on the possible means of recovering petroleum once burned.

24 This relation has also been clearly altered by the evolution of technology over time. The application of more efficient processes permits the reduction of concentration costs, which compensates for the decrease of metal content in the ore, as Mathias Ruth (1995) has analysed for some substances. Nevertheless, technological improvements can never bring real costs below the theoretical costs calculated for reversible systems, which show the theoretical minimum of all possible costs, always positive in virtue of the Second Principle of Thermodynamics.

25 In this work tin and wolfram deposits of the earth's crust were modelled, obtaining their distribution curves, which follow the general form indicated above.

26 I am using this term in the sense pioneered by William Kapp (1950).

27 Barnett and Morse (1963, p.11). Georgescu-Roegen refers to these and other authors in his ironic and documented text 'Energy and economic myths' (1972), collected in Georgescu-Roegen (1976).

28 See Georgescu-Roegen (1976). There is a Spanish edition of Boulding's text previously cited in Daly (ed.) (1989).

29 See Georgescu-Roegen (1976).

30 See J.M. Naredo (1987).

31 This text is a résumé and enlargement of the article by Daly which appears in the dossier about Georgescu-Roegen which the journal *Ecological Economics* published in the same year.

32 See references in ibid.

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10. Globalization Versus Internationalization: Some Implications

Herman E. Daly

10.1 INTRODUCTION

Globalization, considered by many to be the inevitable wave of the future, is frequently confused with internationalization, but is in fact something totally different. Internationalization refers to the increasing importance of international trade, international relations, treaties, alliances, and so on. 'International', of course, means between or among nations. The basic unit remains the nation, even as relations among nations become increasingly necessary and important. Globalization refers to global economic integration of many formerly national economies into one global economy, mainly by free trade and free capital mobility, but also by easy or uncontrolled migration. It is the effective erasure of national boundaries for economic purposes. International trade (governed by comparative advantage) becomes interregional trade (governed by absolute advantage). What was many becomes one.

The very word 'integration' derives from 'integer', meaning one, complete, or whole. Integration is the act of combining into one whole. Since there can be only one whole, only one unity with reference to which parts are integrated, it follows that global economic integration logically implies national economic disintegration. By disintegration I do not mean that the productive plant of each country is annihilated, but rather that its parts are torn out of their national context (disintegrated), in order to be reintegrated into the new whole, the globalized economy. As the saying goes, to make an omelette you have to break some eggs. The disintegration of the national egg is necessary to integrate the global omelette.

In the classical nineteenth-century vision of Smith and Ricardo the national community embraced both national labour and national capital, and these classes cooperated, albeit with conflict, to produce national goods – largely with national natural resources. These national goods then competed in international markets against the goods of other nations, produced by their own national capital/labour teams using their own