Joint Production

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Abstract

While an awareness of joint production (i.e. combined production of at least two goods) played a key role in the early years of classic economics and Marx' thinking, it later fell into oblivion. Environmental crises have brought it back into practical and theoretical discussions. When physicists proved that industrial production is always attended by the manufacture of at least one waste product, they also highlighted the general relevance of this concept for environmental issues. Their proof is based on the first and second laws of thermodynamics.

The added value of this concept is that it shows that the Mainstream Economics' theory of externality is an ex post approach, while the Ecological Economics' concept of joint production provides an ex ante approach. The former recognizes environmental degradation only after it has occurred, whereas the latter focuses on it right from the start.

An example from the soda-chlorine industry illustrates a process that evolved over 250 years. New technologies and products were invented due to resource scarcity. Over the course of time, pollution from the new technology was increasingly recognised, leading to environmental legislation. Thus, we can develop a "triangle of causation": Resource scarcity initiates technological invention, this in turn produces environmental pollution which must be regulated by politics. This process leads to new technological innovation which produces new resource scarcities and new environmental pollution. This is how the textile industry led to the soda-chlorine industry and finally to the production of CFCs (Chlorofluorocarbons) which have destroyed the ozone layer.

Related Concepts: THERMODYNAMICS, HOMO OECONOMICUS & HOMO POLITICUS, ABSOLUTE & RELATIVE SCARCITY, EVOLUTION

1. History

Surprisingly, the concept of joint production played a prominent role in Mainstream Economics' thinking from the 18th century to the end of the 19th century. But it then fell into oblivion until Ecological Economics brought it back to attention and back to the prominence it deserves for understanding environmental and resource problems. Hence, the concept of joint production originates from economics and has a long history. It played an essential role in shaping economic theory for over two centuries. Several great economists elaborated this concept; among them were Adam Smith (1723 – 1790), Johann Heinrich von Thünen (1783 – 1850), John Stuart (1806 – 1873) Mill (1806 – 1873, Karl Marx (1818 – 1883), William Stanley Jevons (1835-1882), Arthur Cecil Pigou (1877 – 1959), Heinrich von Stackelberg (1905 – 1946), John von Neumann (1903 – 1957) and Pierro Sraffa (1898 – 1983) (Baumgärtner et al. 2006). One motivation for the preoccupation with joint production was environmental and resource problems, long before the field of environmental and resource economics as a branch of Mainstream Economics emerged in the second half of the 20th century. For example von Thünen (1921 [1826]: 209) illustrates that dung is a joint effect of consumption and cattle-breeding. To dispose of this bad, the inhabitants and the farmers have to pay for it. Karl Marx (1959 [1894]: 101) notes: "The so-called waste [as a joint product, MF] plays an important role in almost every industry." He elaborates further that there exists a close relationship between industrial production of desired goods and environmental pollution which is caused by undesired goods.

One of the founders of Mainstream Economics, i.e. neoclassical economics, was William Stanley Jevons (1835-82) (see for the following Baumgärtner et al. 2006:116-18). He (1911 [1879]: 198-199) illustrates with many empirical examples that in almost every case of joint production the desired goods are accompanied by other outputs which are not wanted. "When giving examples of things of negative value Jevons (1911 [1879]: 129) reverts to cases of environmental pollution, for example "the sewage of great towns, the foul or poisoned water from mines, dye-works, etc." Also, Jevons identifies the importance of negatively valued joint outputs in the first place as them being the origin of environmental pollution, which is very similar to Marx' view (cf. above)" (Baumgärtner et. al. 2006: 118).

After Jevons the application of the theory of joint production got in oblivion concerning environmental problems (Müller-Fürstenberg 1995: 12-14). Although there is an encompassing area of theoretical and empirical knowledge about joint production in Mainstream Economics this fact does not play a major role in present Mainstream Economics (Baumgärtner et. al. 2006: Chapter 6).

Baumgärtner et al. (2006: 138) state that joint production of desired goods and harmful bads are not explicitly an issue. Instead, Mainstream Economics developed a welfare theory of external effects of production (to be discussed below in Section 2.1) to analyse the basis for environmental problems and to develop policy recommendations to deal with them. One essential drawback of this approach is that the physical basis of production has been long neglected in Mainstream Economics since it concentrated on monetary flows. Thus, the theory of external effect of Mainstream Economics, expressed in value terms, is the counterpart to the joint production approach of Ecological Economics, expressed in physical terms.

Ecological Economics (Boulding 1966, Ayres and Kneese 1969, Georgescu-Roegen 1971) introduced the concept of joint production in a new and original way in the wake of the environmental movement in the late 1950s. Their starting point however was not economic theory but a physical perspective. They employed physics and in particular thermodynamics when they started to analyse economic environmental interactions.

The laws of thermodynamics [see Section 2.4 and for more details THERMODYNAMICS] lead us to recognise that the human economy is an open subsystem embedded in the larger, but finite, system of the natural environment (Boulding 1966, Georgescu-Roegen 1971, Daly 1977, Ayres 1978, Faber et al. 1995[1983], Baumgärtner et al. 2006 and many more). Ecological Economists view nature not as a subsystem of the economy (as Mainstream Economics does), but perceive the economy as a subsystem of nature. This change of perspective was revolutionary (Brown 2001).

Why was this change revolutionary? The reason is that it led to the application of a discipline completely alien to economics, the field of thermodynamics, which is the subdiscipline of physics that deals with energy. It gives rich insights into the physical nature of economy-environment interactions, unknown to Mainstream Economists. Georgescu-Roegen's (1971) path-breaking critique of Mainstream Economics is based on the first two laws of thermodynamics: "But – a fact hard to explain – though the noise caused by the Entropy Law [the second law of thermodynamics, MF] has been in physics and the philosophy of science, economists have failed to pay attention to this law, the most economic of all physical laws" (Georgescu-Roegen 1971: 280).

This finding was the starting point for a thorough and encompassing endeavour to analyse economic-environment interactions in a completely new way, combining economic tools and physical relationships. It has led to new theoretical approaches, such as the concept of joint production, and many empirical studies. Both in turn are a major contribution to environmental policy. Thermodynamic relationships are now widely recognised as an essential element of Ecological Economics.

2. Theory

2.1 Mainstream Economics and the external effects approach

“Within the Mainstream Economics literature with its roots in Welfare Economics, the usual analytical method for understanding environmental damage is through the notion of external effects. There is postulated a relationship between economic actors which is asymmetrical and not mediated by a market; for example, if one smokes in a lift, it causes uncompensated offence to one’s fellow passengers. In the usual externality approach, this relationship is conceptualised as an issue of welfare/utility loss of the person affected by the external effect. That is, the description is based on the effect” (Baumgärtner et.al. 2006: 11). Within the context of a Mainstream Economics’ analysis of environmental problems [Baumol and Oates (1988), Hanley et al. (1997), Kolstad (20009, Siebert (2004), Tietenberg (2003)], joint production is typical modelled in an implicit way, using the economic concept of externality (for example Malinvaud 1985: 232). Externalities express the following kind of interactions between economic agents: The economic activity of agent A influences the well-being or possibilities of economic action of agent B, without A and B having a business relationship concerning that matter. The modelling of such influences is normally done by modelling the effect upon B.

Hence, without effected economic agents or an effect on their valuation, an externality does not exist, hence the corresponding environmental damage is not recognised by society. As some effects of current joint production will show up and can be evaluated only in the future, the concept of externality is not universally suited to capturing the physical phenomenon of joint production. It follows that the welfare effects will only be taken into account once they have been experienced; that is, external effects are matters of the ex post.

This raises the question as to who takes responsibility when the effect is considered much later than its cause [Petersen and Faber 2003, 2004, Baumgärtner et al. 2006: Part III and RESPONSIBILITY], as is the case when a large lake is polluted over the course of many years and the atmosphere is polluted by CO2 over the course of centuries.

An advantage of the theory of external effects is that it is compatible with the theory and instruments developed by Mainstream Economics and thus easy to apply by people with economic training. Hence, there exist many applications [Baumol and Oates (1988), Hanley et al. (1997), Kolstad (20009, Siebert (2004), Tietenberg (2003)].

In summary, Mainstream Economics employs the theory of external effects to capture economic-environment interaction" (Baumgärtner et. al. 2006: 138-141). These effects are called external because their effects are not included in market prices. The repercussions of external effects, however, are often noted much later and much too late. To formulate this aspect more generally: Principal products are consumed in a little while; however, the corresponding bads of their production accumulate over long time scales. This implies that Mainstream Economics utilises an ex-post approach for their analysis: The repercussions of the accumulation processes are often unanticipated [see concept IGNORANCE] and very costly to repair, if at all.

2.2 Joint production in business literature

The business literature approaches the issue of joint production from an applied and empirical point of view. At the centre of attention is the individual production and business unit. Riebel (1981: 296; similarly, 1996: 993), one of the important authors dealing with join production from the business point of view, gives the following definition (our translation): "Out of a single common process of production, two or more different products (only one of which often is desired) necessarily emerge either for natural or for technical reasons".

"While this definition appears to be clear and plausible at first sight, it raises a number of questions (Dyckhoff 1996: 175) and turns out to be too narrow to deal with joint production from an Ecological Economic point of view. For this reason, Dyckhoff (1996) develops a more encompassing definition, which generalises Rebel's definition in an essential and constructive way" (Baumgärtner et. al. 2006: 24). The relationship between Dyckhoff's notion and our notion of joint production is presented in detail in Baumgärtner et al. (2006: 24-42).

We note, however, that the theory of joint production is generally not used in business administration to examine environmental issues, but it is employed to analyse production interdependencies and in particular to assign costs to the various production factors, such as labour, capital good, resources and land, in order to calculate prices of commodities (Riebel 1996).

2.3 The joint production concept

In contrast to the theory of external effects, one could, however, recast this relationship between economic agents starting from the cause of the effect. Very often one would observe that the starting point is an unintended joint product. Therefore, we observe that there exists a duality between an explanation based on the effect, that is the externality approach, and an explanation starting from the cause of the effect, that is the joint production approach.

Ecological Economics has developed an ex ante approach. The cause of environmental pollution and degradation is its starting point. To this end it is expedient to employ the concept of joint production which has a physical underpinning. Since the founding of Ecological Economics in the eighties of the previous century, the concept of joint production has proven to be a central conceptual element of Ecological Economics.

Joint production "denotes the phenomenon that several outputs *necessarily* emerge from economic activity. These joint outputs may all be desired and positively valued goods. But in the vast majority of instances, some of them are undesired and may even harmful to the natural environment.

An example is the refine of crude oil, in which gasoline, kerosene, light-heating oil and other mineral products are produced; but harmful sulphurous wastes and carbon dioxide-emissions are also naturally generated.

The concept of joint production captures the particular characteristic of human activity, namely that it always has unintended side effects, which is the structural cause of many environmental problems. With this, it is a natural starting point for analysing how environmental problems emerge and how they can be solved in a sustainable manner" (Baumgärtner et. al.2006: 2) [SUSTAINABILITY & JUSTICE].

As mentioned in Section 1 above, great economists of the 19th century identified this problem: Thus, Marx notes (Baumgärtner et. al. 2006: 118): "[t]he waste products of a chemical works [...] will sometimes have a low value; at other times it will be difficult to get rid of them without fouling the rivers and injuring the neighbouring estates; in this case they are discommodities and take the negative sign [of marginal utility]" (Jevons 1911[1879]: 202).

To give further illustrations: The occurrence of joint production is well known in the chemical industry. For example, the industrial production of 100 kg soda with the Leblanc process in the 19th century was only possible by manufacturing 69 kg hydrochloric acid, which is a highly poisonous gas, 68 kg calcium sulphide and 83 kg carbon dioxide. Yet joint production is not restricted to industry: German households were responsible for 49.8 Mill tons of waste in 2012. To get an idea of the size of this amount, imagine a garbage dump which is 10 m high, 100 m wide and 49.8 km long. By the way, the corresponding dump for the waste of the rest of the German economy was 330.8 km long. To give a second example, let us examine one involving two persons who need 4000 kWh electrical energy on average per year. If this amount is manufactured from lignite (brown coal), then the following joint products are necessarily produced: 6,000 l water steam, 21,600 m^3 air emissions, 3,200 l waste water and 288 kg ashes.

The advantage of using joint production to analyse environmental issues compared to the theory of external effects developed within Mainstream Economics is that the concept of joint production can alert one to the potential of environmental harm in advance; that is, considering joint production ex ante creates a motive for actively exploring yet unknown negative future welfare effects (Baumgärtner 2000: 293–294; Baumgärtner and Schiller 2001: Section 6).

From our considerations about the theory of external effects and the concept of joint production, we argue that the concepts of joint production and external effects are complementary. (Baumgärtner et al. 2006: 11). While the former should be used ex ante to avoid environmental problems occurring at all, the latter may be employed ex post, i.e. after the environmental damage has already happened, needs to be cleaned up, and avoided in the future.

2.4 Thermodynamics: preparing the ground for working with the joint production concept

Having introduced the concept of joint production, we can step back and look at its foundations, namely how understanding the underlying concept of thermodynamics offers a new perspective on production and on environmental problems.

“Why is joint production such a ubiquitous phenomenon and useful notion in Ecological Economics? We believe that this is because joint production is intimately related to the laws of thermodynamics. The application of thermodynamics is widely recognised as an essential element in much current ecological-economic thought since it gives rich insights into the nature of economy-environment interactions. The laws of thermodynamics lead us to recognise that the human economy is an open subsystem embedded in the larger, but finite, system of the natural environment (Boulding 1966, Georgescu-Roegen 1971, Daly 1977, Ayres 1978, Faber et al. 1995[1983], Baumgärtner et.al. 2006 and many more).

The usefulness of thermodynamics derives from its applicability to all real production processes, which are the basis of economic activity.

- Thus, thermodynamics relates ecological economics to the natural sciences, such as chemistry, biology and ecology, which also facilitates interdisciplinary research.
- The strength of the concept of joint production is that it allows us to incorporate this insight about economy-environment interactions into Ecological Economics. This can be seen in the following argument.

From a thermodynamic point of view, energy and matter are the fundamental factors of production.

- Every process of production is, at root, a transformation of these factors.
- Hence, in this view production processes are subject to the laws of thermodynamics"

(Baumgärtner et. al. 2006: 3-4, THERMODYNAMICS).

2.5 The power and generality of the joint production concept

"The power and generality of the joint production concept can be demonstrated through the way it embraces four central issues in Ecological Economics:

- irreversibility;
- limits to substitution;
- the ubiquity of waste; and
- the limits to growth.

First, irreversibility [THERMODYNAMICS, IRREVERSIBILITY and BASICS ON TIME] is explicitly included within the above thermodynamic formalisation of joint production, as it is necessarily the case that the production process generates irreversible consequences. For example, a ton of coal which is used to generate electricity by burning it, can never be reversed.

Second, *limits to substitution* are also included as the requirement that low concentrated materials inputs must be converted into higher concentrated ones; the manufacturing of desired goods requires that the material inputs be accompanied by an irreducible minimum of highly concentrated fuels.

Third, *the ubiquity of waste* can be easily derived from the thermodynamically founded joint production approach. It follows from the necessity of jointly producing high entropy, which very often is embodied in undesired material, and hence constitutes waste. For example, as mentioned above the production of one kilowatt hour necessarily produces 68 g ashes, 0.8 l waste water, 5.4 cubic m waste gases and 1.5 l vapour waste water.

Fourth, the combination of the above three issues leads to the notion *of limits to growth,* further emphasising the power and generality of the joint production concept for ecological economics" (Baumgärtner et. al. 2006: 5).

3. Practice

The history of the soda-chlorine industry illustrates the usefulness of the concept of joint production for empirical analysis. The first theoretical and empirical study on joint production within the present view of Ecological Economics was carried out by Georg Müller-Fürstenberger (1995), analysing the chemical industry. Further case studies on paper, chlorine, cement and sulphuric acid can be found in Baumgärtner et. al. 2006: 271-338. These case studies "serve to demonstrate the importance of the phenomenon of joint production in ecological-economic systems, to show the potential of the concept of joint production for analysing economy-environment interactions, and to illustrate the general results of the approach obtained so far" (Baumgärtner et. al. 2006.: 271).

3.1 Soda-chlorine industry

The phenomenon of joint production raises two fundamental questions for society.

1. At the cognitive (or epistemological) level, one has to ask: In what way does society recognise joint production?

2. At the level of action, society has to ask: What instance and what authorities are responsible for reducing the harmful or even noxious effects to an extent such that they are tolerable?

While the answer to the former question is a scientific one and therefore refers to reality, the latter refers to the concept of responsibility which originates from the world of the mind and the moral. We shall deal with the latter, which is of central importance for environmental politics, in the concept RESPONSIBILITY. Epistemological aspects of the former are examined in the concept IGNORANCE.

Here we want to demonstrate the power and generality of the concept of joint production for environmental analysis and policy by considering the history of the soda-chlorine industry. It is a story of innovation and industrial evolution; it will lead us from the textile industry to the soda-chlorine industry. Since the chlorine industry comprised 60 % of the German chemical industry in the 20th century, it was a major driver of economic growth.

This enables us to show the effects and interaction of the use of natural resources, the invention and innovation of new techniques due to resource scarcity, the pollution of the environment leading to the invention and innovation of new techniques and, in turn, new goods, which brought new environmental damage etc. This evolution of economic activity and its impact on the environment take us back to the middle of the eighteenth century and ultimately up to the middle of the twenty-first century, i.e. a time scale of three hundred years. This will hopefully give the reader an idea of how important it is to consider economic environmental interaction in the long run.

The textile industry was the first industry. It, therefore, it is often called 'the mother of all industries'. It began in the first half of the eighteenth century. Its development cannot be separated from that of the soda-chlorine industry. In the middle of the eighteenth century, its essential production factor potash was obtained from burning wood. It was needed for bleaching. However, for 1 ton of potash, 1400 tons of birchwood were needed, which soon led to deforestation and thus to resource scarcity. For this reason, it had to be substituted by natural soda which was imported from Egypt and Spain. A steeply rising demand for soda and British sea blockades of the French coasts in the 1760s and 1770s led to shortages in the supply of soda [BASICS OF LIFE]. In 1775 the French Academy announced a prize for the invention of a synthetic production process for soda, which was awarded to the doctor of medicine Nicolas Leblanc in 1791.

It took over 30 years until the Leblanc process was introduced to England on a large scale in 1822, and the scarcity of natural soda could thus be overcome. However, as the chemical description of this production shows, there were three joint products in particular, for 100 kg soda yields as *joint products*: 69 kg HCL (hydrogen chloride), which is a highly *poisonous gas,* 68 kg CaS (calcium sulphide), and 83 kg CO_2 (carbon dioxide).

The poisonous gas hydrogen chloride was released into the air and caused not only damage to the neighbouring agriculture, but in particular to the people living in neighbourhoods around the plants. From 1830, increasing public pressure arose because of serious health problems. The resistance against emissions of hydrogen chloride finally resulted in the passing of the Chlorine Alkali Bill in 1864. As a result, 95 % of the emerging hydrogen chloride had to be converted to hydrochloride acid which was released into neighbouring rivers and lakes. The second join product, calcium sulphide, was deposited in heaps which accumulated to big stocks. At first sight, this seemed to be an adequate solution for this waste product. However, it turned out that chemical reaction within these stocks led to the emergence of water-soluble sulphur compounds. These substances were washed out by precipitation and groundwater, and consequently entered neighbouring bodies of water. These two kinds of pollutants damaged not only the fish stock, but corroded boats' hulls and floodgates. It took another decade until the Chlorine Alkali Bill was amended in 1874 such that the introduction of fluid waste was regulated.

The socio-political pressure which ultimately resulted in the amendment had first initiated research before a legal manifestation came about. The Deacon process was invented in 1869 which made it possible to extract pure chlorine from hydrochloride acid. Since chlorine is a very multifunctional product, it could be sold on the market. Over the course of time, the demand for chlorine grew rapidly such that soda became a by-product of the chlorine production; this is an example of turning an unwanted joint product, a bad, into a wanted one, a good.

For the sake of brevity, we will just mention that the second joint product, calcium sulphide, was also ultimately treated by a chemical process, which was patented in 1883. This made it possible to regaining in elementary form 90 % of the sulphur contained in the waste. Elementary sulphur can be used for many purposes, in particular for sulphuric acid (see for a case study Baumgärtner et. al. 2006: Chapter 18).

At first sight, it appears that the natural resource scarcities were overcome and that the environmental problems had not only been solved, but the bads even turned into goods. The occurrence of joint production, together with adequate socio-political or legal pressure, provides strong incentives to solve technological conservatism and to invest in research and, in turn, in technological development to deal adequately with joint products. Hence, the phenomenon of joint production may be regarded as a trigger to invention and innovation [see EVOLUTION for further comments]. In summary, we can say the ignorance [IGNORANCE] concerning technical progress had positive and negative effects. The positive effects were the result of creativity initiated by the markets. The negative effects, however, could not be solved by the market, only by politics [ENVIRONMENTAL POLITICS].

3.2 Comparison between theory of external effects and theory of joint production

Let us examine the innovation of the Leblanc process and its repercussions for the environment and the people working in the factories, the farmers and the people living in the neighbourhoods surrounding the factories from

1. the perspective of Mainstream Economics, i.e. the theory of external effects and

2. the perspective of Ecological Economics, the theory of joint production.

To 1. The innovation of the Leblanc process was very much welcomed because many jobs were created in the new soda industry and the textile industry, the capitalists earned a lot of profits, and the consumers wanted to have more and different textiles. Only four decades later in 1864, however, the workers, farmers and people living nearby were rescued from the poisonous gas by the Chlorine Alkali Bill, the fishermen only by its amendment in 1874. Here we clearly see the ex-post character of the theory of external effects of Mainstream Economics since it took so long to reduce the environmental problem.

To 2. Had the Ecological Economics theory of joint production been employed during the innovation in 1822, it would have recognised right from the start the disastrous future repercussions of the three *joint products*, HCL (hydrogen chloride), and CaS (calcium sulphide) and CO_2 (carbon dioxide), described in Section 4.1 above. This fact was known to any chemist and could have been communicated easily to the public in general and the politicians in particular. An ex-ante policy measure devised with the theory of joint production would have been realised immediately, which would have prevented so much damage and so much suffering.

3.3 The destruction of the ozone layer: the CFCs

However, the solution to the hydrogen chlorine problem ultimately only resulted in moving the environmental problems linked to chlorine from the *production* sphere to the *consumption* sphere, since the disposal of goods containing chlorine is highly problematic. In particular, burning them leads to extremely poisonous gases, dioxins. It is for this reason that the German Advisory Council for the Environment maintains that in 1990 the expansion of the chlorine industry was a major mistake of the 20th century. We want to illustrate this conclusion using one compound of the chlorine industry, the CFCs, the chlorofluorocarbons. This example demonstrates that the application of the theory of joint production was decisive in avoiding further severe environmental damage.

The chlorofluorocarbons were created experimentally around 1870. They have particularly good characteristics: They are not poisonous, are incombustible and can be employed for very different applications, especially for cooling and heat isolators. They are an essential part of our way of life. Over the course of time, a tremendous number of factories were built to produce refrigerators, freezers, refrigerator trucks and wagons, and cold storage facilities. In 1974, 700,000 tons of CFCs were manufactured, and 350,000 tons of CFCs were emitted from stocks of cooling devices. In 1974 it was discovered that the CFCs, due to their stability, could rise into the stratosphere which is 12 to 35 km over the earth's surface and destroy the ozone layer. The discovery of the destruction of great parts of it in 1984 came as great surprise and shock [IGNORANCE]. Projections show it will take until 2050 before the ozone layer will reach the concentration levels present in 1970. Thus, the history of the CFCs comprises a time span of nearly two centuries. Again, the environmental damage could not be resolved via the market but only by a world-wide international agreement, the so-called Montreal Protocol of 1989.

3.4 Joint production as a comprehensible principle

It is worth pointing out that joint production fulfils an important demand of Ecological Economics, which states that "it is clearly desirable that fundamental concepts of Ecological Economics should be easily comprehensible. It has often been noted in the literature (e.g. Norton 1992) that the scientific approach is sufficient neither for the recognition of environmental problems, nor for their solution. Concerning recognition, as a matter of history, the awareness of environmental degradation was, to a large extent, brought about not by the scientific community, but by laypeople. Often, it was individuals or small groups who first publicly noted that the natural environment was being changed. In everyday life, attentive human beings can recognise many dimensions of the natural environment, while science, by its nature, has to reduce the wholeness of an event to only those aspects to which its methods are suited.

The second important reason why central concepts of Ecological Economics should be easily comprehensible for "the person in the street" concerns the resolution of environmental problems. In democratic societies, decisions about what kind of environmental policy is to be enacted are made (effectively) by ballot. Hence, voters have to understand environmental issues and their proposed solutions.

We have often noted in discussions with scientists who had no background in economics and with laypeople that they were able to comprehend the nature of an environmental problem and to appreciate a proposed solution much more easily when such issues were explained in terms of joint production, rather than in other economic terms, for example production functions, damage functions, externalities, Pigouvian taxes, etc" (Baumgärtner 2006: 9). The reason for this statement is that every lay person can see, smell, hear and feel the joint products of manufacturing; the concepts of mainstream economic mentioned above are very abstract and difficult to understand. Nevertheless, the theory of external effects is, as stated above, a useful approach to analyse environmental issues and to develop policy recommendations.

Finally, it is worth mentioning that the ubiquitous nature of joint production has led physicist, economist and philosophers to jointly analyse the question as to what the relationship is between joint production and responsibility, for if every production is joint production then the question of responsibility has new relevance, not only for economic actors but also for policy makers [RESPONSIBILITY, Petersen and Faber (2003, 2004) and Baumgärtner et al. 2006: Part III Ethics, which deals extensively with the relationship between joint production and responsibility].

4. Literature

The content of MINE originates from scientific work published in books and peer-reviewed journals. Quotes are indicated by a special typographic style.

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Baumgärtner, S., Faber, M. and Schiller, J. (2006), Joint Production and Responsibility in Ecological Economics. On the Foundation of Environmental Policy. Edward Elgar,

4.1 Recommended literature

Key literature

Baumgärtner, S., Faber, M. and Schiller, J. (2006), Joint Production and Responsibility. On the Foundation of Environmental Policy, Edward Elgar, Cheltenham.

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