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Avoiding co-product allocation in the metals sector

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Abstract

Co-production (the combined or joint production of two or more products from the same process or system) has been seen as presenting a problem to the system modelling in life cycle assessment, and the traditional solution has been co-product allocation (the partitioning and distribution of the environmental exchanges of the co-producing process or system over its multiple products according to a chosen allocation key) in parallel to cost allocation. Compared to this traditional solution, system expansion according to ISO 14041 provides a more realistic modelling of the actual consequences of product related management decisions. Through a number of examples, including recycling of steel and aluminium, it is demonstrated how co-product allocation can be avoided in practice. The example of platinum-group metals is used to illustrate how system expansion may sometimes be used as a justification for economic allocation.

Introduction: Co-production in the metals sector

When a process or product system is related to more than one product, it presents a problem to system modelling in life cycle assessment: how should the process or system exchanges, its inputs and outputs, be partitioned and distributed over the multiple products?

Co-production is common to all industrial sectors, and in parallel to most other commodities, the life cycles of metals include co-produced chemicals and co-generated heat and electricity. For the metals themselves, however, co-production occurs most conspicuously in three stages:

- joint production of several different metals, since most metals are found in ores together with other valuable metals,
- joint or combined production of several metal alloys and semi-manufactured products from the same metal base and using the same machinery,
- in relation to recycling, since metals generally maintain their inherent properties and metal scrap therefore is a valuable commodity.

Thus, this presentation will focus on examples for each of these three aspects of the metals life cycle, although the applied procedure is also applicable to all other cases of co-production that may be encountered in the metal supply chains.

Allocation or system expansion?

The traditional answer to the problem of co-production has been allocation, which implies the choice of some allocation key by which the process or system exchanges can be partitioned and distributed over the multiple products. The allocation key has traditionally been e.g. the mass, energy content, or economic value of the co-products. The long debated core problem of co-product allocation has been the difficulty of finding a universal justification for the choice of allocation key (see for example Dove & Boustead (1998) for an entertaining exposé into different possible allocations of zinc production, showing how the result can be affected at random by making small changes in perspective and justification).

In its crude form, where allocation is seen as merely a practical solution to overcome a technical obstacle, no objective justification is warranted, since the allocation does not seek to model any real life situation. However, if a relation to industrial reality is desired, the justification must be found in the degree to which the parameter chosen as allocation key determines the exchanges of the co-producing process or system.

In this way, an allocation according to product mass is justifiable when this mass is actually determining the volume of the flows of the co-producing process. This will be the case in many situations of combined production of metal alloys and semi-manufactured products from the same raw material. Many of the process exchanges involved are determined by the mass of the products they process: An increase in output of a specific co-product will incur an increase in production volume in proportion to the mass of the co-product.

Similarly, an economic allocation (according to the economic value or gross margin of the co-products) is justifiable when the volume of the co-producing process actually varies in proportion to the changes in the economic revenue to the process from the different co-products. This is typically the case for joint production of different metals from the same ore, when there are no alternative production routes or substitutes for the metals in question.

In both cases, the allocation key that is justifiable in one situation may not be justifiable in the other situation. No allocation key can have global applicability. Also, allocation has an inherent limitation in that it only addresses the partitioning of the co-producing process or system, but not the situations where the demand for a co-product affects processes outside the co-producing process or system. Such situations can only be dealt with through system expansion.

What has been missing, is a unifying theory that can explain what allocation key is justifiable in each specific situation. Also, a unifying theory must cover the situations where system expansion is required.

Such a unifying theory was presented by Weidema (2001) and will be applied below to the typical co-production situations of the metals sector. The basis of the unifying theory is the understanding that any procedure dealing with co-production must seek to reflect as closely as possible the consequences of a specific change in demand for a co-product. This is the explicit aim of the procedure that has become known as “system expansion,” which therefore becomes the core of the unified theory.

Also, system expansion is clearly the most wide-reaching procedure for dealing with co-production, as it involves not only the co-producing process but also any displaced processes, any changes in parallel applications of the determining co-products, and any further treatment of the other co-products (see figure 1). Thus, allocation can be described as a special case of the system expansion procedure, applicable in such situations where only the co-producing process is affected by the change in demand for a co-product. Examples of this will follow.

Basing the unified theory on system expansion also avoids any conflicts with ISO 14041, which requires the use of system expansion whenever possible.

System expansion when the by-product has another main production route

The basic concepts in system expansion are most easily understood when considering a situation where one of the co-products are clearly not influencing the volume of the co-producing process, as for example the sulphur by-product in European zinc mining. In Europe, sulphur is increasingly produced from desulphurisation of flue gases from refineries, power plants etc. This implies that a change in demand for sulphur no longer affects the primary production of sulphur but rather determines how much of the sulphur from desulphurisation will be utilised (process D in figure 1) and the price of this. The output from zinc mining will not be affected by fluctuations in sulphur demand nor price, but will be solely determined by the demand for zinc. This implies that the increase in sulphur output associated with an increased zinc output will lead to displacement of the alternative sulphur supply or – when this output is not determined by demand – to an increased deposit or alternative application of sulphur (process W or B in figure 1). The fate of the additional supply of sulphur, and what processes are affected, thus depends strongly on the actual market conditions. Based on knowledge of the sulphur market, the zinc system (process A) is either expanded with process W or B or with the displaced process D, the latter implying a credit to the zinc system, since an *increase* in process A leads to a *decrease* in process D.

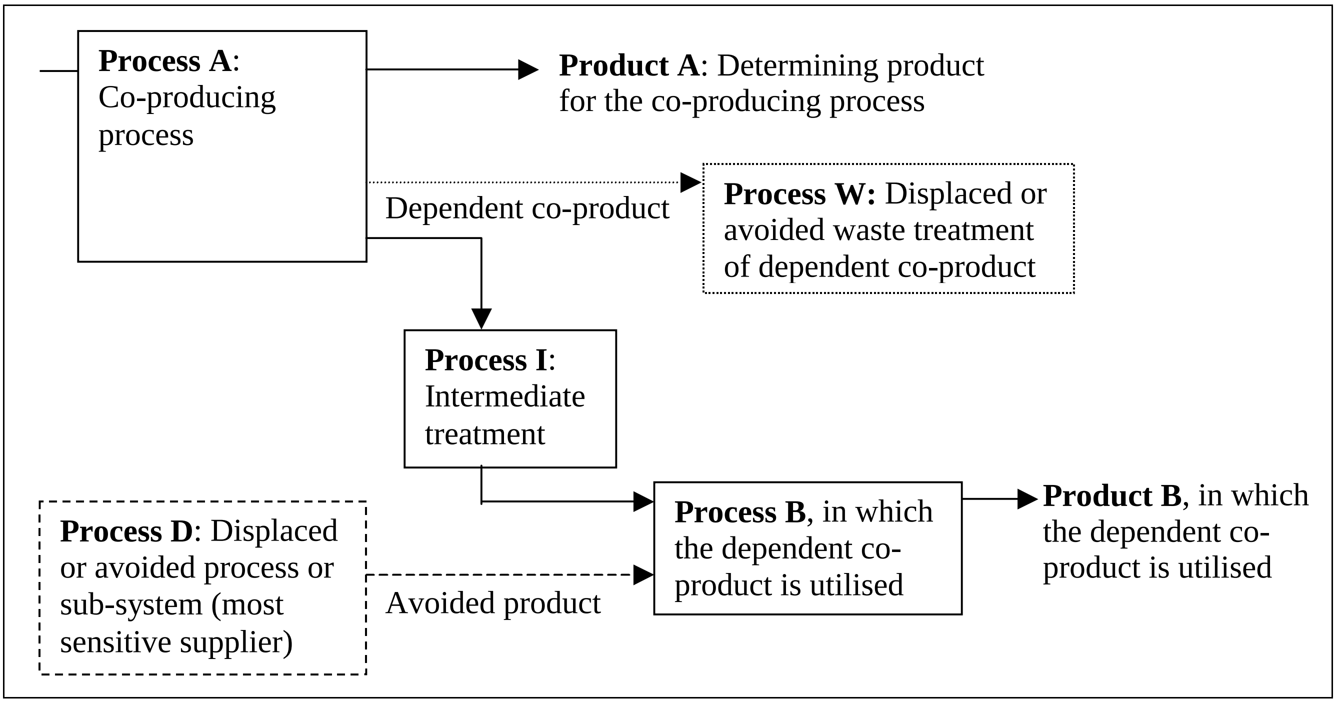

Figure 1 *Model for describing system expansion and delimitation for joint production, valid both when product A and product B is the product used in the life cycle study.*

Similar considerations can be applied to the lead and cadmium by-products from zinc mining. The demand for zinc is increasing moderately, while the demand for the heavy metals cadmium and lead is stagnating mainly due to environmental regulations. The supply of cadmium from compulsory take-back and recycling of cadmium-containing products means that some primary cadmium is currently deposited and the same situation can be expected in the future for the other heavy metals. Thus, it should be clear that only changes in demand for zinc will be able to influence the size of the primary extraction.

Since the volume of primary extraction (process A) is determined by the demand for zinc, it is obvious that this process should be included 100% in the product system for zinc, and that allocation of this process thereby is avoided. To the extent that the dependent co-products lead to displacement of alternative production routes, the zinc product system is credited for this displacement.

System expansion when several co-products influence the co-producing process

When the co-producing process is the only production route for a co-product, it is obvious that the alternative production route (process D in figure 1) does not exist. Platinum and rhodium may be an example of this situation. In this situation, the jointly produced metals can be simultaneously determining for the volume of the joint production process. The prices of all the jointly produced metals are continuously adjusted so that all products are sold. In accordance with standard economic theory, a change in demand for one of the metals will influence the total volume of production in proportion to the gross margin obtained for this metal, relative to the average gross margin for the entire production. This is equivalent to the result of an economic allocation of the joint production process. With relative prices of 1:4 for platinum and rhodium, the same increase in production would then be expected from an increased demand for 1 kg platinum as from an increased demand for 0.25 kg rhodium. Since there are no alternative production routes, the resulting change in production volume in turn affects the output, pricing and consequent consumption of the other jointly produced metals. With relative outputs of 10:1 for platinum and rhodium, their relative prices would imply that for each kg demand for platinum, only 1*11/14 kg platinum could actually be expected as a result, while for each kg demand for rhodium 4*11/14 kg rhodium could be expected. Under the given condition, that there are no alternative production routes, the implicit assumption is that the difference will be made up by changes in consumption in other product systems. The resulting influence on these other product systems must be considered, thus requiring a system model that includes all processes significantly affected in all the life cycles of the jointly produced metals. This latter aspect of system expansion is ignored in a pure economic allocation of the joint production. This system expansion may appear as a complex modelling task, but it should be noted that it is not all applications of the metals that need to be modelled, since the change in supply of a metal will typically be neutralised by the application most sensitive to this change, as identified by the procedure of Weidema et al. (1999). Based on market information from Cowley & Hankin (2001) it appears that the missing platinum would come from a decrease in consumption of jewellery, while the additional rhodium would be used in automobile catalytical converters.

However, rather than a change in consumption of autocatalysts, it is likely that the additional rhodium will simply displace palladium in the same application, in which case we have a situation where palladium plays the role of the alternative production route (process D in figure 1). In contrast to the other platinum group metals, the output of palladium is not intimately linked to the output of the other metals, since the dominating supply from Russia has a low ratio of by-production of other platinum group metals (platinum/palladium/rhodium ratios of 10/50/1 as opposed to the South African ratios 10/5/1). It is important to note that the alternative production route does not need to produce the same material, but must provide a substitute for the service provided by the co-product. Likewise, the missing platinum may in fact not come from a reduction in consumption of jewellery, but rather from a substitution with gold in the cheaper end of the market, so that gold plays the role of the alternative production route.

Based on the relatively stable market trends of the last 10 years (Cowley & Hankin 2001), it appears that rhodium – in spite of its relatively low weight ratio - can be regarded as the determining product for the production volume of the platinum group metals, with palladium and platinum as dependent by-products with either alternative production routes (the Russian supply) or marginal substitutes (gold) as displaced processes.

It is, however, recommended to apply both of the two scenarios outlined above (system expansion with and without economic allocation of the co-producing process) in a sensitivity analysis.

The mining for platinum group metals have further metal co-products, notably nickel, copper, gold and silver, which all have alternative production routes that allow the overall quantity to be regulated independently. The co-products ruthenium, iridium and cobalt are all regarded as dependent co-products that cannot influence the overall production volume of the joint mining operations.

Combined production

Although the ratio between the different metals is relatively invariable within each ore, the output of co-produced metals may still be varied independently when viewing the mining industry as a whole, simply by adjusting the output volume from ores of different composition. Thus, when regarded in its totality, the mining industry can to a large extent be regarded as combined production, rather than as joint production. This allows a simple solution to the co-production issue, namely to isolate the effects of a change in the output of the metal of interest, while keeping the other metal outputs constant. But as demonstrated with the palladium example, this can also be expressed in terms of a system expansion.

The same metal raw material is typically the source of many different semi-manufactured products and combined in different alloys. The output volume of each product can typically be varied independently, i.e. a situation of combined production. The simple way to analyse this situation is to study the changes in the combined production as the output of the product of interest is varied, while keeping the other product outputs constant. Typically, exchanges from the combined production depend on a simple physical parameter, often the mass of the products processed. In such cases, the result will be identical to an allocation according to product mass. This analysis is equivalent to step 2 of the ISO 14041 procedure for handling co-products, the so-called “allocation according to physical relationships.” In practice, the analysis does not involve system expansion, but formally it can be expressed as a special case of system expansion when the limiting parameter for the combined production is used as the determining co-product, and the non-limiting parameters are the dependent co-products (Weidema, in press).

System expansion for recycling

For metals recycling, the system expansion model in figure 1 must be interpreted so that process A is the first life cycle and process B is the subsequent life cycle in which the scrap from the first life cycle is used. The determining co-product for process A is then the service delivered by the first life cycle and the scrap is the dependent co-product.

In an expanding market for the scrap product, such as is the case for steel, aluminium and most other metals, all scrap collected will be used. In this situation, a change in the volume of either life cycle will lead to the displacement of “virgin” production volume. Supplying more scrap from the first life cycle will increase the amount of recycling and displace “virgin” production volume, while a change in the volume of the secondary life cycle must be covered by a change in “virgin” production, because the scrap is already utilised fully. This has also been pointed out by other authors, e.g. IISI (1997).

In immature markets, the recycling might be below the economic optimum due to capacity constraints. In this situation, neither using nor supplying scrap will affect the recycling rate. An increase in demand will thus affect “virgin” supply, while an increase in supply to recycling will increase waste deposits. Only a specific action to remove the capacity constraints on recycling will effectively increase recycling.

In some situations, the recycled metal cannot displace “virgin” metal due to contamination or alloying (e.g. copper in iron scrap, and silicon alloys of aluminium that cannot be recycled with the ordinary aluminium scrap). In these cases, sometimes described as downcycling, several distinct markets may exist for different qualities of recycled metal, and the displacements that will occur will be determined by the supply and demand on these markets. It should be noted that it is not only the current market situation that must be considered, but rather a very long-term market situation. As long as the current demand for scrap qualities is larger than the supply, all the contaminated scrap will be used and will displace “virgin” material. The contamination will be diluted due to the constant inflow of virgin material. However, at some stage in the future the scrap markets may become saturated, so that the contamination becomes a limitation for the recycling (this is already happening with copper contamination in iron scrap). The current contamination may thus lead to a future need for waste treatment of the contaminated material, or at least to a different displacement than on the current market (see e.g. Kakudate et al. 2000, Holmberg et al. 2001). It is this future market situation that should be used to determine what processes to include in the system expansion, since the immediate displacement of “virgin” material is only a temporary postponement of the necessary supply of “virgin” material in the future situation, when the contaminated material can no longer be used. The need to take into account these future effects is included in the rule: “If there are differences between a dependent co-product and the product it displaces, and if these differences cause any changes in the further life cycles in which the co-product is used, these changes shall be ascribed to product A” (Weidema 2001).

Conclusions (relations to ISO)

It has been demonstrated that all situations of co-production in the metals sector may be handled through system expansion, either in its typical form or in specific forms for cases of combined production and cases where more than one co-product influence the co-producing process. The specific forms can be seen as representing allocation by physical relationships (ISO step 2) and allocation according to economic value (ISO step 3).

When ISO step 2 and 3 can be expressed as special cases of system expansion (ISO step 1), the step-wise nature of the ISO procedure becomes unnecessary. Simply describing the application area of each step in the procedure, as suggested here, would give a more straightforward presentation.

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