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Coupling attributional *and* consequential life cycle assessment: A matter of social responsibility

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ABSTRACT

A long-running debate within the life cycle assessment literature concerns the appropriate uses for attributional and consequential forms of life cycle assessment. A recently published contribution to this debate suggests that social responsibility necessarily requires a consequential perspective, and that taking an attributional perspective is optional, but not necessary. The present paper critiques this suggestion by exploring two limitations with only taking a consequential perspective. First, consequential assessments are not additive, in the sense that when added they do not approximate to total aggregate environmental burdens. Second, consequential assessments are not suitable for creating an initial scope of responsibility, as the number of possible decisions available to an agent may be intractably large, and the notion of 'role' responsibility is not defined by specific decisions and consequences. This second limitation is derived from a previously identified parallel between attributional and consequential methods and the normative ethical theories of deontology and consequentialism. Based on the exploration of the two limitations, a coupled accounting solution is proposed which uses both consequential and attributional approaches for different but complementary purposes. The paper concludes by suggesting that although the debate on attributional versus consequential methods has occurred largely within the field of life cycle assessment, the proposed coupled accounting solution has broader applicability to other areas of social and environmental accounting.

1. Introduction

This article is written largely in response to Weidema et al.'s (2018) paper titled 'Attributional or consequential life cycle assessment: a matter of social responsibility', which is a recent addition to a long-running debate within the life cycle assessment (LCA) literature on the appropriate use of 'attributional' and 'consequential' forms of LCA. This debate traces back to 1993, with Weidema's original observation that none of the published guidance for LCA at the time 'adequately reflects the importance that market aspects and the economic disciplines may have in life cycle inventory methodology' (Weidema, 1993, p. 161). Weidema suggested that life cycle inventories should reflect 'to the largest extent possible, the actual consequences of implementing the results of the investigation' (Weidema, 1993, p. 166). This emphasis on quantifying the consequences of a decision is the essence of the 'consequential' approach, and can be contrasted with quantifying the environmental burdens associated with the processes directly used or physically connected with the product studied, which is the essence of the 'attributional' approach (Brander and Ascui, 2016).

A more formal definition of the attributional-consequential distinction is supplied by UNEP/SETAC, which define attributional LCA as a 'modelling approach in which inputs and outputs are attributed to the functional unit of a product system by linking and/or partitioning the unit processes of the system according to a normative rule' (2011, p. 132). In contrast, consequential LCA is defined as a 'modelling approach in which activities in a product system are linked so that activities are included in the product system to the extent that they are expected to change as a consequence of a change in demand for the functional unit' (2011, p. 133).

The labels 'attributional' and 'consequential' themselves did not emerge until an international LCA workshop in 2001 (Curran et al., 2005; Ekvall and Weidema, 2004), and by 2008 Finnveden was able

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to state that there 'is today a general agreement within the life cycle assessment (LCA) community that there are two types of LCA … These are often called attributional and consequential LCA' (2008, p. 365). Although there may be broad agreement on the *existence* of the distinction, there remains considerable disagreement on the appropriate uses of the two different approaches. At one extreme, Wenzel (1998) suggests that the only purpose of an LCA is to inform decision-making, and therefore the only appropriate method is a consequential one, as it is only this approach that aims to quantify the total consequences of decisions. In contrast, Tillman (2000) argues that although decision-making is central to life cycle assessment there is still a role for attributional LCA, such as the 'identification of improvement possibilities' (2000, p. 120). In addition to suggesting that there are appropriate uses for attributional LCA, the arguments in Tillman (2000) also mingle concerns about the practical feasibility of consequential LCA, e.g. the difficulty in identifying the systems that change as a result of a decision.

A more recent contribution to this debate is Plevin et al.'s article 'Using attributional life cycle assessment to estimate climate-change mitigation benefits misleads policy markers' (Plevin et al., 2014a), which prompted numerous replies (Brandão et al., 2014; Dale and Kim, 2014; Hertwich, 2014; Suh and Yang, 2014), and counter-replies (Plevin et al., 2014b, 2014c). The key argument in Plevin et al. (2014a) is largely the same as that in Wenzel (1998), i.e. attributional LCA does not aim to quantify the total change caused by the decision in question, and that this information is essential for rational decision-making. However, contrary to Wenzel, Plevin et al. do allow that attributional LCA may have some appropriate uses such as 'normative analyses (e.g., when allocating responsibility for environmental harm)' (2014a, p. 79).

The arguments in response to Plevin et al. (2014a) are also similar to those in Tillman (2000), i.e. methods for quantifying system-wide change, e.g. economic models, may not accurately predict how systems will change (Dale and Kim, 2014; Suh and Yang, 2014); and there are still appropriate uses for attributional LCA, such as product labelling or as a metric for regulatory compliance (Brandão et al., 2014). In response, Plevin et al. accept that methods for quantifying system-wide change may be uncertain, but argue that this uncertainty represents our state of knowledge of the consequences of the decision in question, which is decision-relevant information in its own right, i.e. options that we know have positive outcomes under all plausible scenarios should be preferred to those that do not (Plevin et al., 2014a). Plevin et al. do not respond specifically on the issue of what the remaining appropriate uses of attributional LCA are, but do emphasize that 'we do not argue against all uses of ALCA [attributional life cycle assessment]' (2014c, p. 1560).

One of the most recent contributions in this long lineage is Weidema et al. (2018), which takes the debate in a new direction by focusing on the concept of *responsibility*. It argues that the 'literal meaning of responsibility implies a focus on consequences that can be meaningfully acted upon and changed' (Weidema et al., 2018, p. 312) and that a 'consistent socially responsible decision-maker *must* always take responsibility for the activities in the consequential product life cycle and *may* additionally take responsibility for consequences of other activities in the value chain or supply chain' (2018, p. 313). In other words, consequential LCA is essential, while attributional LCA is optional.

The present paper seeks to advance the debate by critiquing this contention (i.e. that consequential LCA is essential, while attributional LCA is optional) by exploring two limitations with the consequential perspective. Moreover, these limitations can be overcome by using an attributional approach, and therefore both approaches are necessary for managing social or environmental responsibility. The paper proceeds as follows: sections 2 and 3 analyse the identified first and second limitations respectively; section 4 proposes a coupled accounting solution, which uses both consequential and attributional approaches for different but complementary purposes; section 5 discusses strengths and potential objections to the proposed approach, similarities and differences with other approaches previously suggested in the literature, and the main implications of the paper for theory and practice; the final section concludes by highlighting the applicability of the findings to other forms of social and environmental accounting.

2. First limitation: additivity

A first limitation with only using a consequential method is the lack of additivity, i.e. the results from consequential assessments cannot be summed to approximate total aggregate environmental impacts. Tillman (2000) offers two distinct interpretations of additivity, and it is therefore worth analysing and clarifying which is genuinely a limitation for consequential LCA. One interpretation is that an 'important characteristic of an accounting LCA [i.e. attributional LCA] is that of additivity, so that, for example, a LCA of a waste water system can easily be added to one for, say, a detergent.' (2000, p. 116). While a second interpretation of additivity is that 'LCA results of all the products in the world should add up to the total environmental impact in the world' (2000, pp. 116–117). These two interpretations of additivity are not necessarily equivalent, and it appears that consequential LCA may be additive in the first sense, but not the second.

Considering the first sense of additivity, a consequential LCA for a waste water system (i.e. for an increase in demand for waste water treatment) could be combined with a consequential LCA for detergent (i.e. an increase in demand for detergent) to provide an overall assessment of the change caused by the decision to 'produce more waste water and use more detergent'. There may be a problem if the two assessments are undertaken separately but there are interaction effects between the two decisions (e.g. if the detergent assessment itself assumes a specific level of demand for waste water treatment which does not hold true if the separate decision to increase demand for waste water treatment has been taken). However, such cases may be unlikely, or if they do occur it would be possible to undertake the consequential LCAs sequentially and then add them together (which would capture any interaction effects). It may be true that it is easier to add separate attributional LCAs together, as interaction effects do not arise when modelling or allocating environmental burdens within a static system, but this form of additivity does not appear to be an insurmountable or *in principle* limitation for consequential LCA.

In contrast, the second interpretation of additivity (i.e. 'LCA results of all the products in the world should add up to the total environmental impact in the world') does appear to be something that consequential LCA cannot provide. This is because consequential LCA is concerned with marginal systems, i.e. the systems that change as a result of the decision studied (Ekvall and Weidema, 2004), rather than average systems or the product systems that are physically consumed. This is illustrated in Fig. 1 which provides a schematic 'order of dispatch', i.e. the order in which product systems will enter into production to meet demand within a market, and the greenhouse gas intensity of the different product systems. For a consequential LCA, if the baseline level of aggregate demand in the market is $Demand_1$ then any subsequent decision that increases demand (e.g. to $Demand_2$) will cause an increase in the production of Product D, i.e. Product D is the marginal system. Even if a consumer decides to purchase and consume Product A (perhaps because Product A has the lowest emissions intensity) the actual change in emissions caused by the decision is the amount of emissions associated with the marginal system (Product D). This is

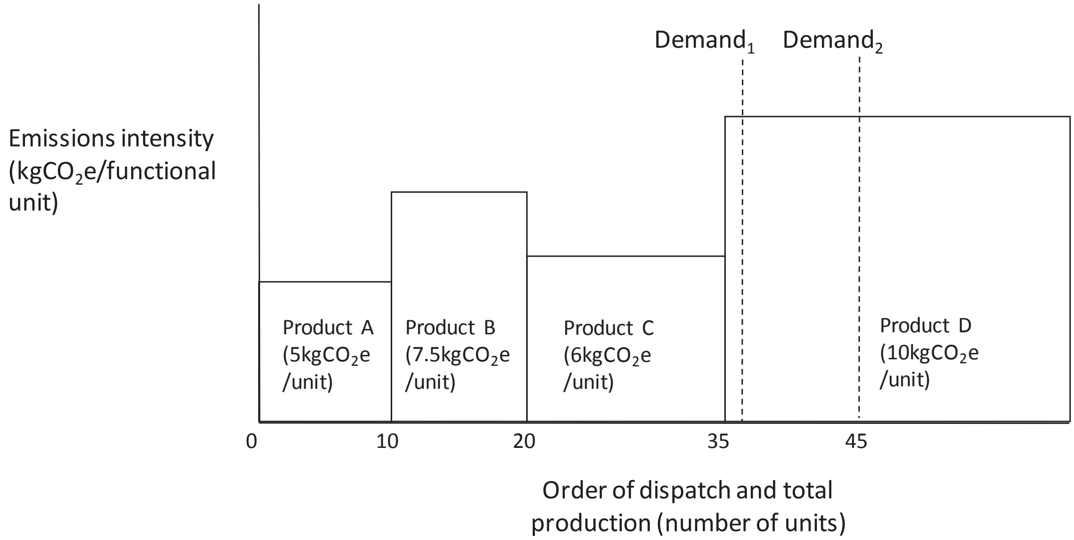

Fig. 1. Order of dispatch for product systems within a market.

because the production of Product A is already at its maximum capacity. Choosing to consume Product A only displaces existing consumers of Product A who then consume alternative products in the market, and ultimately total demand can only be met by increasing the production of the marginal system (Product D).

Relating this to the issue of additivity, consequential LCA only studies the marginal system, and therefore only provides information on the change in emissions caused by an additional unit of Product D (10 $kgCO_2e$/unit). If this is multiplied by the total number of products produced (10 $kgCO_2e$/unit * 45 units) the result is 450 $kgCO_2e$, whereas total emissions to the atmosphere are 315 $kgCO_2e$ (calculated as per Equation 1, or the area of each box in the order of dispatch up to the level of total demand), i.e. consequential LCA cannot be used to estimate total aggregate environmental impact.

Equation 1. Calculation of total aggregate emissions

$$\text{Total Emissions} = \sum_m TP_{m,y} * EF_{m,y}$$

TP_m = Total production from product system m
EF_m = Emissions factor for product system m
$_m$ = Each product system supplying the market
$_y$ = The relevant time period for the analysis, e.g. a year

Furthermore, consequential LCA treats cases of multi-functionality (e.g. the production of co-products) by a method called *substitution*, which involves identifying the product systems that are displaced by the production of co-functions, and crediting the displacement of those product systems to the decision studied, as the avoidance of those systems is a consequence of the decision (Weidema et al., 2009). This entails that consequential assessments do not represent, nor are they intended to represent, actual aggregate emissions to the atmosphere (Brander and Wylie, 2011), and therefore the sum of consequential LCA results for all the products in the world will not 'add up to the total environmental impact in the world' (Tillman, 2000, pp. 116–117).

This limitation is an important one, as arguably sustainability is a system-level attribute rather than a characteristic of individual practices, i.e. it is not possible to achieve sustainability if aggregate levels of consumption or resource use exceed system-level sustainable thresholds (Gray, 2010). Recognition of this underpins initiatives such as 'science-based target setting' (Science Based Targets Initiative, 2015), which aims to ensure that corporate greenhouse gas (GHG) reduction targets are aligned with global carbon budgets. For example, the sectoral-decarbonisation approach (SDA) involves estimating the level of future production and available carbon budgets for different sectors of the economy, and from this emissions-intensity targets are derived for companies within each sector (Science Based Targets Initiative, 2015). In theory, if the targets are met then the GHG emissions from all companies and all sectors should sum to a total that does not exceed the global carbon budget, e.g. between 550 and 1300 $GtCO_2$ between 2011 and 2050 for a 2 °C target increase in global temperature (Krabbe et al., 2015). Similar initiatives have been discussed in relation to life cycle assessment, i.e. for translating planetary boundaries into per capita allowances (Frischknecht et al., 2016). The important point is that consequential LCA cannot be used for such purposes, because the results are not additive to total aggregate impacts, and therefore Weidema et al.'s (2018) contention that only consequential LCA is essential, while attributional LCA is optional, appears problematic.

3. Second limitation: initial scope of responsibility

A second limitation with only using a consequential method is derived from the insight, originally proposed by Ekvall et al. (2005), that attributional and consequential LCA correspond to the normative ethical theories of deontology and consequentialism. Broadly, deontic ethical theories determine the rightness of an action by its conformance to a rule (Van Staveren, 2007), and consequential (or 'telic') theories determine the rightness of an action by its consequences (Scheffler, 1988). The respective emphasis on either rules or consequences parallels the UNEP/SETAC definitions of attributional and consequential LCA given above, with the attributional boundary determined by 'a normative rule' and the consequential boundary determined by the 'consequence of a change'. In addition to identifying a second limitation with only using a consequential approach, the distinction between deontic and consequential ethics is also useful for developing the proposed 'coupled accounting' solution (in Section 4), and it is therefore worth articulating these normative ethical theories in some detail.

One archetypal deontological theory is Kant's categorical imperative, which, under one formulation, states ‘Act in such a way that you treat humanity, whether in your own person or in any other person, always at the same time as an end, never merely as a means’ (Kant, 2002, sec. 4:429). One of the arguments in support of this rule is that all value is conferred by humanity, and therefore if humans value anything they must value humanity (Korsgaard, 1996). Such a rule creates limits to actions regardless of the consequences of the action, e.g. it is not right to harm an innocent person, even if doing so has consequences that increase total human happiness (as humans should be treated as ends and ‘never merely as a means’). Deontic ethics is also often referred to as *duty* ethics, as the ethical rule binds the agent to their duty (Ransome and Sampford, 2010). A key point for the purposes of the present discussion is the primacy of *rules* within the deontic approach, rather than the consequences or outcomes from an action.

In contrast, consequential ethics holds that ‘the right act in any given situation is the one that will produce the best overall outcome, as judged from an impersonal standpoint which gives equal weight to the interests of everyone’ (Scheffler, 1988, p. 1). An archetypal consequential theory is utilitarianism, which states that the ‘greatest happiness for the greatest number is the measure of right and wrong’ (Bentham, 1948, p. 3). One of the central features of what Scheffler (1988) describes as ‘pure’ consequentialism is its impartiality or agent-neutrality, i.e., all interests are given equal weight. According to this view of consequentialism, ‘act’ consequentialism is a pure form, as individual agents are required to impartially consider the aggregate or system-wide consequences of their actions. In contrast, ‘rule’ consequentialism, which judges the rightness of an act based on whether it conforms to a rule which achieves the greatest beneficial consequences (Shafer-Landau, 2013), is less ‘pure’ as it opens to door to agent-relativism, if the rule which generates the greatest beneficial consequences involves some degree of agent-relative self-interest. An example of such a case is Adam Smith's famous justification for individual economic self-interest, which argues that it is ‘not from the benevolence of the butcher, the brewer or the baker that we expect our dinner, but from their regard to their own self-interest’ (Smith, 1976, pp. 26–27). Following Scheffler (1988), agent-neutrality or impartiality is treated here as a defining feature of pure consequential ethics, and this feature is also clearly present within consequential LCA. For example, Weidema et al. state that the ‘socially optimal action for any organisation at any specific point in time is to change the specific activities that provide the currently most cost-efficient environmental improvement, no matter whether these activities show up as important within the specific value chains, supply chains, or product life cycles of the organisation’ (2018, p. 311).

Turning now to the second limitation with taking only a consequential approach, it is possible to identify how some of the weaknesses associated with ethical consequentialism may also apply to consequential LCA. One criticism of the agent-neutrality inherent in consequentialism is that it becomes excessively demanding (Scheffler, 1988), if, for example, the universe of possible actions that are available at any point in time has to be considered. The enormity of this requirement becomes apparent when it is recognised that responsibility extends to actions that could have been taken but were not, and also to actions by others that could have been prevented, but were not. As recognised by Weidema et al. ‘inaction, i.e. the omission of action in a situation where action could have been taken, has consequences’ (Weidema et al., 2018, p. 311), and by Williams ‘ … if I am ever responsible for anything, then I must be just as much responsible for things that I allow or fail to prevent, as I am for things that I myself, in the more everyday restricted sense, bring about’ (Williams, 1995, p. 95).

The problem with consequentialism is that the number of potential decisions or options may be intractably large, and being unaware of all the possible options does not limit responsibility, i.e. if it is within the power of an agent to implement an option then they are responsible for any consequences from not having done so. This problem is different from the arguments concerning the practical feasibility of identifying the consequences of decisions previously raised in the literature (Dale and Kim, 2014; Suh and Yang, 2014; Tillman, 2000), as the issue is not the feasibility of identifying the consequences of a decision relative to a business-as-usual or zero-action baseline, but rather the feasibility of identifying all the decisions or actions that could be taken at any point in time.

A further potential limitation with consequentialism is that there must always be a specific decision in question, the consequences of which constitute the responsibility of the agent. However, there are types of responsibility, notably ‘role’ responsibility, which are not concerned with specific actions, but instead involve on-going ‘care and attention over a protracted period of time’ (Hart, 1968, p. 213), e.g. the kind of responsibility parents have for their children. ‘Role’ responsibility appears to be highly applicable to producers (and consumers too), e.g. producers may feel they have a ‘role’ as stewards of their supply or value chain, and are therefore responsible for that supply/value chain, independently of any specific decision or action. An example, borrowed from Weidema et al. (2018), is a food company that uses wild fish which have been caught using high-impact bottom trawling. Regardless of any decision or whether the company's purchase of the fish causes the impact (i.e. the production system using the bottom trawling may not be the marginal system, and so would happen anyway), there is an intuitive sense of responsibility, or duty of care.

Consequentialism appears to struggle with establishing an initial scope of responsibility, either because the number of potential decisions available may be intractably large, or because some intuitively held forms of responsibility are prior to and independent of specific decisions or actions. In contrast, a deontic/attributional approach appears able to handle exactly these issues. Such an approach defines the scope of responsibility according to a normative rule, and can therefore create a clearly bounded scope that the agent in question is responsible for, e.g. ‘All the impacts associated with the processes used in the physical supply chain’. Similarly, deontic/attributional approaches can define responsibility without reference to a specific decision or action, and can therefore encapsulate ‘role’ responsibility too. This is not to say that consequentialism is incapable of encapsulating other aspects of responsibility, e.g. ‘causal’ responsibility (Hart, 1968), but that there are some forms of responsibility that it cannot accommodate, and therefore consequentialism on its own, contrary to Weidema et al. (2018), is not sufficient. This suggests that both attributional and consequential approaches are necessary for adequately defining and managing responsibility.

4. Proposal for a coupled accounting approach

To briefly summarise, the two identified limitations with only using a consequential method are: first, the results from consequential LCA do not sum to approximate total aggregate environmental impacts; and, second, consequential assessments are not suitable for creating an initial scope of responsibility. Ekvall et al. (2005, p. 1232) suggest that the solution to the attributional-consequential debate is to recognise that the two approaches can ‘result in complementary information’, but provide relatively little detail on how this might be done. This section therefore sets out a proposal for how attributional and consequential methods should be used to complement each other within a coupled accounting approach, drawing on the respective strengths of each perspective.

The first step in the proposed coupled accounting approach is to use an attributional method to define an initial sphere of responsibility for the agent in question, in order to create a sense of ownership for a specific set of impacts. A consequential approach does not appear to be appropriate for this purpose, given the issues discussed above. A further reason for using an attributional approach to define an initial sphere of responsibility is that it is then conceptually possible to sum individual assignments of impacts to estimate total aggregate impacts to the environment, to set reduction targets based on global thresholds or budgets, and to track progress over time. This approach also helps address the point that sustainability is a system-level attribute, and that individual organisational or consumer accounting is largely meaningless if it does not reflect the overall sustainability of the system (Gray, 2010).

The second step in the proposed coupled accounting approach is to use a consequential method to assess the system-wide consequences of any decisions aimed at managing the impacts within the attributional (rule-defined) scope of responsibility, because there is no environmental benefit in reducing impacts within an attributionally defined inventory if total impacts are increased elsewhere (for example, see Searchinger et al.'s (2008) critique of US biofuel policy). This second step also embodies the strong consequentialist intuition that agents should be responsible for the system-wide consequences of their decisions (Lasswell and Kaplan, 1950; Scheffler, 1988). Fig. 2 sets out the structure of the proposed coupled accounting approach.

Returning to the example of the food company, the following is a simple illustration of how the coupled accounting approach would work. In Step 1 the food company would define its scope of responsibility by undertaking an attributional account of its impacts (e.g. based on the physical processes within its value chain). This scope of responsibility would include the high-impact bottom trawling used to catch the fish the company purchases. The company then sets a target for reducing its impacts, e.g. a 50% reduction in the impacts from bottom trawling in 2 years' time (a sophisticated target-setting approach would be to estimate the capacity of the fishing ground to sustain bottom trawling and the company's share of that sustainable ‘budget’). In Step 2 the food company considers the option of switching its purchasing to farmed fish, as this would only involve a small increase in cost and would reduce

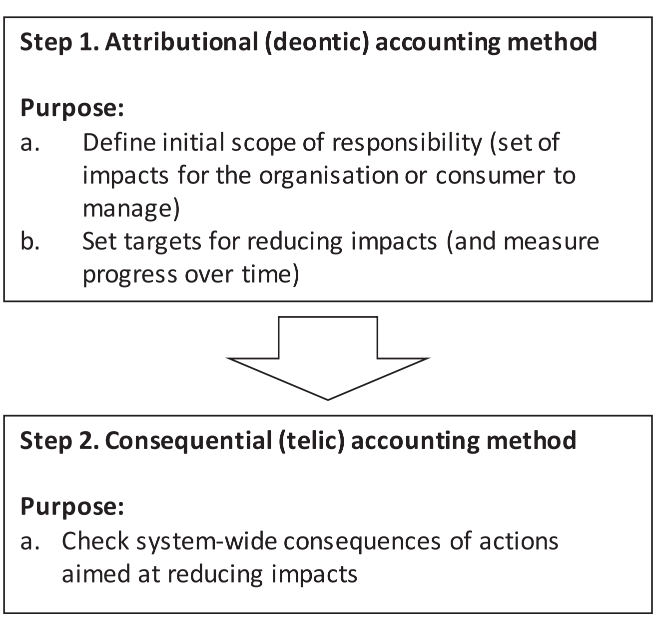

Fig. 2. Structure of coupled accounting approach.

bottom trawling impacts in the attributional account to zero. However (in accordance with Step 2), the company conducts a consequential assessment to estimate the system-wide change in impacts caused by the decision and finds that other food companies would most likely purchase the wild caught fish (as it is lower cost) and there would be no change in total environmental impacts. Instead, and after assessing the option with a consequential method, the food company chooses to engage with the trawler company to implement low-impact fishing gear.

It is worth emphasizing that this proposed approach is not suggesting that attributional and consequential elements should be blended within a single analysis, as is unintentionally done in ISO 14044 (Brander and Wylie, 2011; Weidema, 2014), but rather that separate attributional and consequential methods can be used in combination, with each applied to their appropriate purpose. It is also worth emphasizing that although the proposed approach offers a different view from that in Weidema et al. (2018), by arguing for the necessity of attributional methods, it is important to underscore that, given the widespread misuse of attributional methods for decisions about actions, only consequential methods are conceptually appropriate for this purpose.

5. Discussion

5.1. Strengths and potential objections to the proposed approach

One indication of the conceptual coherence of the proposed coupled accounting approach is that it fulfils the two criteria for assigning responsibility in Rodrigues et al. (2006) that Weidema et al. (2018) identify as being mutually exclusive if they are required of a single approach. The two conflicting criteria in Rodrigues et al. (2006) are:

> ‘that environmental responsibility should verify a normalization condition, such that the sum of the environmental responsibility of all agents should equal total environmental pressure [i.e. additivity]’ (2006, p. 259);

and

> ‘that the indicator should not display wrong signals, only allowing for a decrease in environmental responsibility of an agent if there was a decrease in overall direct environmental pressure.’ (2006, p. 259).

Weidema et al. correctly point out that these ‘are mutually exclusive conditions, since the first refers to - and can only be fulfilled in - a steady-state analysis of environmental pressure and the second condition refers to a change in environmental pressure and can only be fulfilled in an analysis of changes, which is not possible in the analysed steady-state system.’ (2018, p. 306). One strength of the coupled accounting approach is that it fulfils both of these criteria, but without the incoherence of attempting to fulfil them in a single method, i.e. an attributional method is necessary for the first criterion, and a consequential method is necessary for the second.

A potential objection to the necessity of the first criterion (i.e. the requirement for additivity), and by implication a partial rejection of the necessity of using an attributional method, is that ‘several actors can assume full responsibility, so that responsibility is not a conserved quantity like mass’ (Weidema et al., 2018, p. 308). However, there is no incompatibility between multiple actors taking responsibility for the same impact and ensuring additivity. A good example of an environmental accounting approach that achieves both is the use of ‘scopes’ within corporate-level GHG accounting, in which 'scope 1' emissions are from facilities controlled by the reporting entity, 'scope 2' emissions are from the generation of purchased energy (e.g. electricity), and 'scope 3' are from any other source within the reporting entity's value chain (WBCSD/WRI, 2004). More than one actor can take responsibility for the same emissions, e.g. scope 1 emissions for the electricity generator will be scope 2 emissions for the consumer of the electricity, but additivity is still achieved (i.e. summing only scope 1 emissions will approximate to total emissions).

A different potential objection to the proposed coupled accounting approach is a problem associated with using an attributional method to create the initial scope of responsibility, i.e. that it 'is inconsistent for a socially responsible decision maker to exclude consequences of own actions (i.e. the consequential life cycle) while including consequences from actions of others in the value chain or supply chain' (Weidema et al., 2018, p. 306). In other words, because the attributional boundary is defined by normative rules rather than consequences, the initial sphere of responsibility may include impacts that cannot actually be influenced by the agent, and/or may exclude impacts that can be. One partial solution to this problem is to screen the attributionally defined inventory to exclude impacts that cannot be influenced by the agent in question. An example of such an approach within corporate-level GHG accounting is the GHG Protocol *Corporate Value Chain (Scope 3) Accounting and Reporting Standard,* which states that companies 'should prioritize activities in the value chain where the reporting company has the potential to influence GHG reductions' (WBCSD/WRI, 2011, p. 61). It is also important to note that using a consequential method does not appear to be a viable alternative, given the potentially intractable number of possible actions that would have to be considered, and the inability to capture 'role' responsibility.

A further related problem is how to choose between the following two options: 1. an action which reduces the impacts within the attributionally defined inventory, and which does not increase impacts elsewhere in the system; or 2. an action which does not reduce impacts within the attributionally defined inventory, but which reduces total system-wide impacts more than the first option (T. Ekvall 2017, pers. comm., 28 November). Something akin to this issue arises with corporate-level GHG accounting and what can be termed 'product-enabled reductions', which are reductions enabled by a company's products (e.g. low-temperature detergents, fuel-saving tyres, or teleconferencing services etc.), but the reductions are not captured within the attributional boundary of scopes 1, 2, or 3 (World Resources Institute, 2013). One existing option for reporting reductions in impacts that occur outside the attributional inventory is a 'gross-net' approach, in which the gross figure is the attributional inventory and the net figure is an adjusted total reflecting the change in emissions occurring outside the attributional inventory (for an example of this approach see Defra's guidance on environmental reporting (Defra, 2013)). Such an approach would encourage, but not necessarily require, actions that maximise system-wide benefits.

5.2. Differentiation from other reconciliations

There are a number of papers in the literature that also discuss the relationship between attributional and consequential methods, and propose possible reconciliations, and it is important to highlight how the present paper supports or differs from these positions. Firstly, Sandén and Karlström (2007) suggest that a 'constructive approach is to conduct attributional LCAs based on relevant future states or scenarios of consecutive states to guide the direction of actions. To assess decisions directly, a consequential perspective is needed' (2007, p. 1479). This approach is similar to that of the present paper, in that it envisages using an attributional method as a starting point, and that a consequential method is required to assess specific decisions. An additional, rather than contradictory, point made in the present paper is that an attributional approach is *necessary* for establishing an initial scope of responsibility, prior to consideration of future scenarios or improvement decisions. A different area of alignment is Sandén and Karlström's intimation that attributional and consequential methods should not be mixed in a single analysis, ' … attributional and consequential perspectives are mixed. This opens up for somewhat misleading interpretations … ' (2007, p. 1479).

A more recent paper, that builds on aspects of Sandén and Karlström (2007), is Arvidsson et al. (2016), which suggests that a 'first order consequential study of the substitution [of graphene for indium tin oxide in electrodes] is methodologically identical to a comparison between two prospective attributional studies' (2016, p. 290). This appears at odds with the contention in the present paper that consequential and attributional methods are fundamentally distinct approaches that are appropriate for different (but complementary) purposes. One caveat to Arvidsson et al.'s statement is that the equivalence holds if only 'first order' effects are considered, i.e. the physical flows used in the life cycle of the product(s) in question (Sandén and Karlström, 2007). With this caveat, the equivalence appears to be achieved by restricting the 'consequential' assessment to the normative boundary of an attributional approach, whereas a full consequential study would include second order (i.e. market-mediated) and, ideally, third order (e.g. positive feedback from learning) effects.

Arguably a more thorough-going equivalence between attributional and consequential approaches would be achieved, in principle, by describing two complete macro-level attributional scenarios (i.e. all the physical flows within each system), and then comparing those scenarios to provide an estimate of the system-wide change caused by switching from one scenario to the other. The crucial requirement for this to work is that the macro-level scenarios should include all the processes that change, i.e. there are no effects that occur outside the boundary of the macro-level scenarios. Notably, both Sandén and Karlström (2007) and Arvidsson et al. (2016) focus on large or technology-scale (rather than product-level) changes, for which macro-level scenario comparisons are highly applicable, and could (given the requirement above) capture total system-wide change. However, once the preferred macro-level scenario has been identified it is still necessary to choose specific actions and policies for achieving that scenario, which is the point made by a Sandén and Karlström (2007) quoted above (i.e. to 'assess decisions directly, a consequential perspective is needed' (2007, p. 1479)). A potential addition to the proposed coupled accounting approach could therefore be an optional 'Step 1c: If considering a technology-scale change, macro-level attributional scenarios can be useful for estimating the difference in total impacts between the scenarios'.

A further recent study which has some similarities, but also some important differences, with the present paper is Yang (2016), which offers 'a two-step approach to CLCA [consequential LCA] based on the attributional framework' (2016, p. 277). The first step involves conducting an attributional LCA to 'evaluate the status quo of the system under study and identify hotspots on which we can focus subsequently' (2016, p. 277) and the second step involves modifying attributional LCA to make it more suitable for assessing change, e.g. using marginal instead of average coefficients. The first step is broadly similar to that proposed in the present paper (though, again, the additional contribution from the arguments presented above is that they establish the *necessity* of using an attributional method for setting an initial scope of responsibility). However, the second step in Yang (2016) appears to be somewhat problematic as it involves adopting some (but not all) of the features of consequential LCA, with the outcome that the results would not represent an estimation of system-wide change, and nor do they maintain the key characteristics of an attributional approach, e.g. additivity. As noted by Sandén and Karlström (2007), mixing attributional and consequential methods results in 'misleading interpretations', and rather than attempting to make attributional methods something that they are not (i.e. facsimiles of consequential methods), the present paper suggests that it is better to recognise the purposes for which they are uniquely useful.

5.3. Implications for theory and practice

The principle theoretical contribution of this paper is towards conceptualising the distinction between attributional and consequential methods, with the development of such a categorical framework (Denzin, 1970), and the formulation of normative rules (Suddaby, 2014), constituting forms of theory development. Previous studies that have sought to establish the distinction between attributional and consequential methods tend to present a negative case, i.e. by showing what attributional methods should not be used for (e.g. Plevin et al., 2014a), whereas the present paper provides a positive case for the distinction, by showing the uses for which attributional methods are uniquely appropriate.

The major implication for practice is that both attributional and consequential methods are necessary for managing social and environmental responsibility (with each method appropriate for different purposes), and that a single method is not sufficient. This idea, and the proposed way in which each method should be used, is currently not well-established or recognised within the practitioner community. For example, the recently published ISO 14067 standard for the carbon footprinting of products (ISO, 2018) does not state whether it provides an attributional or consequential method, or whether it is appropriate for determining an initial sphere of responsibility (which may be summed to approximate total global emissions), or whether it is appropriate for quantifying the system-wide change in emissions caused by a change in demand for the product. When this standard is due for review in 2023, a recommendation to ISO is to clarify which type of method the standard is intended to provide, and its appropriate use. The benefit for the field of practice would be to ensure that the correct method is used for its appropriate purpose.

6. Conclusions

The purpose of this paper is to contribute to the ongoing debate on the appropriate use of attributional and consequential LCA, and specifically to critique the recent suggestion that a consequential approach is essential, while an attributional approach is optional. The analysis presented here shows that there are limitations to consequentialism, and that these limitations can only be addressed by using an attributional approach. A coupled accounting approach is proposed which explicitly recognises and utilises the respective merits of the two methods.

The argument presented here on attributional and consequential approaches has been framed within the context of life cycle assessment, though reference is also made to lessons that can be drawn from corporate-level GHG accounting. It is worth broadening the horizons of the current debate to recognise that the attributional-consequential distinction is highly applicable as a general framework for categorising many other forms of social and environmental accounting. That is, inventories of social and environmental impacts, whether at the product, corporate, city, or national level can be categorised as 'attributional' in nature, while any assessment of system-wide change can be categorised as 'consequential'. Recognising attributional and consequential methods as categorical 'families' creates the possibility of sharing methodological lessons or innovations between methods of the same type (Brander, 2016). It also entails that the proposed coupled accounting approach is equally applicable to corporate, city, and national-level accounting, as well as product LCA. One potentially significant policy implication is from applying this to the emerging GHG accounting practices for Nationally Determined Contributions (NDCs) under the Paris Agreement (UNFCCC, 2015). At present most countries' NDCs are specified with reference to their national production-based GHG inventories (i.e. normatively defined attributional inventories), but without the requirement that any actions aimed at achieving emission reductions should be assessed using consequential methods. A strong recommendation, based on the coupled accounting approach proposed above, is that governments should use consequential as well as attributional methods.

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References

Arvidsson, R., Kushnir, D., Molander, S., Sandén, B.A., 2016. Energy and resource use assessment of graphene as a substitute for indium tin oxide in transparent electrodes. J. Clean. Prod. 132, 289–297. https://doi.org/10.1016/j.jclepro.2015.04.076.

Bentham, J., 1948. A Fragment on Government. Basil Blackwell, Oxford, UK.

Brandão, M., Clift, R., Cowie, A., Greenhalgh, S., 2014. The use of life cycle assessment in the support of robust (climate) policy making: comment on "using attributional life cycle assessment to estimate climate-change mitigation. J. Ind. Ecol. 18, 461–463. https://doi.org/10.1111/jiec.12152.

Brander, M., 2016. Transposing lessons between different forms of consequential greenhouse gas accounting: lessons for consequential life cycle assessment, project-level accounting, and policy-level accounting. J. Clean. Prod. 112. https://doi.org/10.1016/j.jclepro.2015.05.101.

Brander, M., Ascui, F., 2016. The attributional-consequential distinction and its applicability to corporate carbon accounting. In: Schaltegger, S., Zvezdov, D., Alvarez Etxeberria, I., Csutora, M., Günther, E. (Eds.), Corporate Carbon and Climate Accounting. Springer, Cham. https://doi.org/10.1007/978-3-319-27718-9_5.

Brander, M., Wylie, C., 2011. The use of substitution in attributional life cycle assessment. Greenh. Gas Meas. Manag. 1, 161–166. https://doi.org/10.1080/20430779.2011.637670.

Curran, M.A., Mann, M., Norris, G., 2005. The international workshop on electricity data for life cycle inventories. J. Clean. Prod. 13, 853–862. https://doi.org/10.1016/j.jclepro.2002.03.001.

Dale, B.E., Kim, S., 2014. Can the predictions of consequential life cycle assessment Be tested in the real world? Comment on "using attributional life cycle assessment to estimate climate-change mitigation.". J. Ind. Ecol. 18, 466–467. https://doi.org/10.1111/jiec.12151.

Defra, 2013. Environmental Reporting Guidelines: Including Mandatory Greenhouse Gas Emissions Reporting Guidance. Department for the Environment, Food and Rural Affairs, London, UK.

Denzin, N.K., 1970. The Research Act in Sociology. Butterworth, London.

Ekvall, T., Tillman, A.-M., Molander, S., 2005. Normative ethics and methodology for life cycle assessment. J. Clean. Prod. 13, 1225–1234. https://doi.org/10.1016/j.jclepro.2005.05.010.

Ekvall, T., Weidema, B., 2004. System boundaries and input data in consequential life cycle inventory analysis. Int. J. Life Cycle Assess. 9, 161–171. https://doi.org/10.1007/BF02994190.

Finnveden, G., 2008. A world with CO2 caps. Int. J. Life Cycle Assess. 13, 365–367. https://doi.org/10.1007/s11367-008-0014-z.

Frischknecht, R., Stolz, P., Tschümperlin, L., 2016. National environmental footprints and planetary boundaries: from methodology to policy implementation 59th LCA forum, Swiss Federal Institute of Technology, Zürich, June 12, 2015. Int. J. Life Cycle Assess. 21, 601–605. https://doi.org/10.1007/s11367-016-1053-5.

Gray, R., 2010. Is accounting for sustainability actually accounting for sustainability…and how would we know? An exploration of narratives of organisations and the planet. Account. Org. Soc. 35, 47–62. https://doi.org/10.1016/j.aos.2009.

04.006.
Hart, H.L.A., 1968. Punishment and Responsibility. Oxford University Press, London, UK.
Hertwich, E., 2014. Understanding the climate mitigation benefits of product systems: comment on "using attributional life cycle assessment to estimate climate-change mitigation. J. Ind. Ecol. 18, 464–465. https://doi.org/10.1111/jiec.12150.
ISO, 2018. ISO 14067 - Greenhouse Gases - Carbon Footprint of Products - Requirements and Guidelines for Quantification. Geneva, Switzerland.
Kant, I., 2002. Groundwork for the Metaphysics of Morals. Oxford University Press, Oxford, UK.
Korsgaard, C., 1996. The authority of reflection. In: Korsgaard, C., O'Neill, O. (Eds.), The Sources of Normativity. Cambridge University Press, Cambridge, UK, pp. 90–130. https://doi.org/10.1017/CBO9780511554476.005.
Krabbe, O., Linthorst, G., Blok, K., Crijns-Graus, W., Van Vuuren, D.P., Höhne, N., Faria, P., Aden, N., Pineda, A.C., 2015. Aligning corporate greenhouse-gas emissions targets with climate goals. Nat. Clim. Change 5, 1057–1060. https://doi.org/10.1038/nclimate2770.
Lasswell, H.D., Kaplan, A., 1950. Power and Society: A Framework for Political Enquiry. Yale University Press, New Haven, CT, USA.
Plevin, R.J., Delucchi, M.A., Creutzig, F., 2014a. Using attributional life cycle assessment to estimate climate-change mitigation benefits misleads policy makers. J. Ind. Ecol. 18, 73–83. https://doi.org/10.1111/jiec.12074.
Plevin, R.J., Delucchi, M., Creutzig, F., 2014b. Response to comments on "using attributional life cycle assessment to estimate climate-change mitigation. J. Ind. Ecol. 18, 468–470. https://doi.org/10.1111/jiec.12153.
Plevin, R.J., Delucchi, M., Creutzig, F., 2014c. Response to "on the uncanny capabilities of consequential LCA" by Sangwon Suh and Yi Yang. Int. J. Life Cycle Assess. 19, 1559–1560. Int J Life Cycle Assess, doi: 10.1007/s11367-014-0739-9. https://doi.org/10.1007/s11367-014-0766-6.
Ransome, W., Sampford, C., 2010. Ethics and Socially Responsible Investment: A Philosophical Approach. Ashgate Publishing, Farnham, UK.
Rodrigues, J., Domingos, T., Giljum, S., Schneider, F., 2006. Designing an indicator of environmental responsibility. Ecol. Econ. 59, 256–266. https://doi.org/10.1016/j.ecolecon.2005.10.002.
Sandén, B.A., Karlström, M., 2007. Positive and negative feedback in consequential life-cycle assessment. J. Clean. Prod. 15, 1469–1481. https://doi.org/10.1016/j.jclepro.2006.03.005.
Scheffler, S., 1988. Introduction. In: Scheffler, S. (Ed.), Consequentialism and its Critics. Oxford University Press, Oxford, UK, pp. 1–13.
Science Based Targets Initiative, 2015. Sectoral Decarbonisation Approach: A Method for Setting Corporate Emission Reduction Targets in Line with Climate Science.
Searchinger, T., Heimlich, R., Houghton, R. a, Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., Yu, T.-H., 2008. Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. Science (80-.) 319, 1238–1240. https://doi.org/10.1126/science.1151861.
Shafer-Landau, R., 2013. Ethical Theory: an Anthology, Blackwell Philosophy Anthologies. Blackwell Publishers Ltd, Malden, USA, and Oxford, UK.
Smith, A., 1976. An Inquiry into the Nature and Causes of the Wealth of Nations. Oxford University Press, Oxford, UK.
Suddaby, R., 2014. Editor's comments: why theory? Acad. Manag. Rev. 39, 407–411. https://doi.org/10.5465/amr.2014.0252.
Suh, S., Yang, Y., 2014. On the uncanny capabilities of consequential LCA. Int. J. Life Cycle Assess. 19, 1179–1184. https://doi.org/10.1007/s11367-014-0739-9.
Tillman, A.-M., 2000. Significance of decision-making for LCA methodology. Environ. Impact Assess. Rev. 20, 113–123. https://doi.org/10.1016/S0195-9255(99)00035-9.
UNEP, SETAC, 2011. Global Guidance Principles for Life Cycle Assessment Databases. Nairobi, Kenya.
UNFCCC, 2015. Paris Agreement. Bonn, Germany.
Van Staveren, I., 2007. Beyond utilitarianism and deontology: ethics in economics. Rev. Polit. Econ. 19, 21–35. https://doi.org/10.1080/09538250601080776.
WBCSD/WRI, 2011. GHG Protocol Corporate Value Chain (Scope 3) and Product Life Cycle Standards - Fact Sheet. World Business Council for Sustainable Development and World Resources Institute, Washington, D.C., USA.
WBCSD/WRI, 2004. Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard. Geneva, Switzerland and Washington, DC, USA.
Weidema, B., 2014. Has ISO 14040/44 failed its role as a standard for life cycle assessment? J. Ind. Ecol. 18, 324–326. https://doi.org/10.1111/jiec.12139.
Weidema, B., 1993. Market aspects in product life cycle inventory methodology. J. Clean. Prod. 1, 161–166.
Weidema, B., Ekvall, T., Heijungs, R., 2009. Guidelines for Application of Deepened and Broadened LCA. Rome.
Weidema, B.P., Pizzol, M., Schmidt, J., Thoma, G., 2018. Attributional or consequential Life Cycle Assessment: a matter of social responsibility. J. Clean. Prod. 174, 305–314. https://doi.org/10.1016/j.jclepro.2017.10.340.
Wenzel, H., 1998. Application dependency of LCA methodology: key variables and their mode of influencing the method. Int. J. Life Cycle Assess. 3, 281–288. https://doi.org/10.1007/BF02979837.
Williams, B., 1995. A critique of consequentialism. In: Smart, J.J., Williams, B. (Eds.), Utilitarianism: for and against. Cambridge University Press, Cambridge, UK, pp. 77–150.
World Resources Institute, 2013. Do We Need a Standard to Calculate "Avoided Emissions" [WWW Document]. http://www.wri.org/blog/2013/11/do-we-need-standard-calculate-"avoided-emissions" (accessed 6.7.18).
Yang, Y., 2016. Two sides of the same coin: consequential life cycle assessment based on the attributional framework. J. Clean. Prod. 127, 1–15. https://doi.org/10.1016/j.jclepro.2016.03.089.