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A New Triple-Bottom-Line Accounting Approach

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Unravelling the Impacts of Supply Chains - A New Triple-Bottom-Line Accounting Approach

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Abstract

Companies wishing to realise broader societal and environmental objectives often chose Triple Bottom Line (TBL) accounting as a reporting approach, covering social, economic and environmental indicators and thus enabling decision-makers to quantify trade-offs between different facets of sustainability. Two issues are critical when considering TBL accounting. First, indicators must include both the direct (on-site, immediate) effects of the company as well as the indirect (off-site, upstream, embodied) effects associated with purchasing from a potentially large and distant web of suppliers. The incorporation of all indirect or upstream impacts removes problems related to the choice of boundaries. Second, it is important to address the question of how to assign responsibility for the indirect impacts as they are shared between all partners in a supply chain and must not be double-counted.

The research question of this work is therefore "how can corporate sustainability performance be quantified and compared in practice, whilst taking into account the responsibility sharing nature of trading and avoiding double-counting of impacts?". We a) describe the analytical approach to measure the indirect impacts of a comprehensive Triple Bottom Line account of a producing entity, b) present a quantitative concept of shared responsibility as a solution to assigning responsibility to both producers and consumers, in a mutually exclusive and collectively exhaustive way, and c) demonstrate practical applications in examples of quantification of indirect impacts, supply chain contributions and shared responsibility.

Keywords

Triple Bottom Line accounting, corporate responsibility, shared responsibility, sustainability reporting, input-output analysis, benchmarking, supply chain analysis

1. Introduction

1.1. Corporate Sustainability Reporting and the Triple Bottom Line

A broadly agreed definition of sustainability is: practices and development that meets the needs of the current generation without compromising the ability of future generations to meet their needs (WCED, 1987). Although this definition has been widely accepted, applying it in a meaningful way to all levels of society is a major intellectual and governance challenge. Sustainability is ultimately an absolute condition: a country, community or company is either sustainable or it is not. However, un-sustainability may be less recognisable over immediate or short time scales that are at odds with the accepted principle of sustainability defined in terms of future generations. Therefore, in an operational sense and with our current limited knowledge, sustainability is best viewed as a process. It is likely therefore that the sustainability 'goal posts' will be continually moved as our understanding of the importance of social and natural capital increases. Whilst it is difficult to make an absolute assessment of what sustainability means, proxy indicators of sustainability, many of which are currently in use, are essential for determining relative performance.

Corporations are beginning to apply the concept of sustainability at a practical level in terms of environmental and sustainability accounting and reporting (von Ahsen et al., 2004) (Schaltegger et al., 2006; Taplin et al., 2006; Daub, 2007), thus addressing the various "corporate sustainability challenges" (Schaltegger et al., 2003). Since companies began publishing the first environmental reports in the late 1980s, there has been "a clear tendency towards the inclusion of societal, and sometimes also financial, issues and benchmarking of performance" (Kolk, 2004). Corporate sustainability accounts and reports must contain qualitative and quantitative information on the economic, environmental and social effectiveness and efficiency and integrate these aspects in a sustainability management system (Schaltegger and Wagner, 2006).

Companies wishing to realise broader societal and environmental objectives often chose Triple Bottom Line (TBL) accounting as a reporting approach, covering all three dimensions of sustainability and thus enabling decision-makers to quantify trade-offs between different facets of sustainability. "Triple Bottom Line" is a term originally coined by John Elkington[1] in 1994 to describe corporations moving beyond reporting only on their financial "bottom line" to assessing and reporting on the three spheres of sustainability: economic, social and environmental. TBL can be viewed as a reporting device (e.g. information presented in annual reports) and/or an approach to improving decision-making and the fundamental functioning of organisations (e.g. the provision of tools and frameworks for considering the economic, environmental and social implications of decisions, products, operations, future plans, etc).

TBL provides a framework for measuring and reporting corporate performance against economic, social and environmental benchmarks. Reporting on the Triple Bottom Line makes transparent the organisation's decisions that explicitly take into consideration impacts on the environment and people, as well as on financial capital. The TBL process can reduce risk, assist in delivering better outcomes for employees, shareholders, customers and clients, and enhance reputation. These benefits can help to produce a healthy operating environment and a reasonable expectation of company longevity past the quarterly report of key performance indicators. It has been recognised that managing sustainability performance and successfully

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1 His book "Cannibals with Forks: The Triple Bottom Line of 21st Century Business" (Elkington, 1997) introduced the concept of the Triple Bottom Line to a wider audience, asking whether capitalism itself was sustainable and looking at the ways in which TBL thinking would transform (financial) accounting.

integrating social, environmental and economic objectives in proactive operational strategies go hand in hand with the competitiveness of the business (Schaltegger et al., 2006; Schaltegger and Wagner, 2006).

The concepts of TBL and associated systems and reporting frameworks are increasingly being taken up by companies worldwide as the Global Reporting Initiative (GRI)[2] and the work of bodies such as the OECD build momentum. In the wake of this work national and international regulations are changing and companies are more and more required to report their environmental and wider sustainability performance.[3] This brings with it a need for standardisation of accounting frameworks (Steven, 2004). However, there are no strict guidelines or standards yet with which businesses have to comply. Although the GRI has chosen the notion of the Triple Bottom Line in laying the groundwork for such guidelines (Global Reporting Initiative, 2002), the TBL accounting procedures envisaged by the GRI are still fraught with inconsistencies, amongst which is the so-called boundary problem (Global Reporting Initiative, 2005). This problem can be solved by a comprehensive input-output based life-cycle approach that can be integrated into a TBL framework and applied to supply chain management issues at a wide range of organisational scales (Foran et al., 2005a).

Accounting free of boundary problems and double-counting is particularly important when it comes to quantifying environmental, social and economic impacts, as corporate sustainability performance can only be measured and compared if indicators can be quantified in a robust and reproducible way (see also Krajnc and Glavic, 2005). Two issues are particularly critical when considering quantitative TBL accounting. First, indicators must include both the direct (on-site, immediate) effects of a company as well as the indirect (off-site, upstream, embodied) effects associated with purchasing from a potentially large and distant web of suppliers. Only when adopting this life-cycle perspective, accurate comparisons of performance become possible. Problems related to the choice of boundaries can be avoided by incorporating all possible indirect or upstream impacts. Second, it is important to address the question of how to assign responsibility for these indirect impacts as all partners in a supply chain are involved in their creation and reporting on them must avoid double-counting.

These two issues form the central theme of this contribution. We suggest to undertake an input-output-based life-cycle assessment across social, economic and environmental indicators spanning the entire supply chain of business operations in order to enumerate corporate Triple Bottom Line impacts in a holistic way. We describe the concept of 'shared responsibility' (Section 1.2) and explain with a simplified supply chain example how it can be applied in practical circumstances (Section 3.2).

Perhaps the first of such a consistent and comprehensive life-cycle TBL study of the industrial sectors of an entire economy is the analysis of the Australian economy (Foran et al., 2005b). This analysis – called "Balancing Act" – uses the economic National Accounts, environmental accounts, physical satellite accounts, and input-output techniques in order to characterise 135 industry sectors in terms of four financial, three social and four environmental indicators. For each of the 135 sectors, every indicator is enumerated in a supply-chain context, where all upstream impacts are included.

Researchers at the University of Sydney have developed the underlying methodology for the Balancing Act study and created a TBL software tool, termed Bottomline$^{\mathbf{3}}$ ("BL-cubed").[4] A company's financial accounts, together with on-site impact data, act as input. Software outputs include aggregate figures, detailed breakdowns and rankings of economic, social and environmental indicators. Sector benchmarking, structural

2 http://www.globalreporting.org

3 The EU Accounts Modernisation Directive (AMD), for example, introduces requirements for (large) companies to include a balanced and comprehensive analysis of the development and performance of the business in their Directors' Report. The analysis should "include both financial and, where appropriate, non-financial key performance indicators relevant to the particular business, including information relating to environmental and employee matters". This part of the EU Accounts Modernisation Directive is effective for financial years beginning on or after 1 April 2005.

4 Currently, there is an Australian (www.bottomline3.com) and a United Kingdom version (www.bottomline3.co.uk) of this tool available.

path analysis (upstream supply chain analysis) and production layer decomposition are available for all TBL indicators. Quantification of shared responsibility is realised by delineating impacts into mutually exclusive and collectively exhaustive portions of responsibility to be shared by all agents along a supply chain. In this contribution we use example outputs from the tool to demonstrate how TBL impacts from a business' operations can be quantified in a systematic and comparable way.[5]

The need for such robust tools and information for quantitative environmental and sustainability reporting is growing rapidly and will persist in the future. A recent report from the London-based environmental consultancy Trucost, published by the UK Department for the Environment, Food and Rural Affairs (DEFRA, 2006), hints at significant gaps:

- "… there is still a lack of quantification in most reporting. The Environment Agency study of Annual Reports and Accounts of the FTSE All Share companies, noted that the majority of reports lack depth, rigour or quantification. The study concluded that quantified environmental disclosure levels in Annual Reports and Accounts were found to be low…" (page 14) and
- "Most business will have supply chain impacts that they should understand and consider reporting. There is no single, quantifiable measure that companies can use as a KPI [Key Performance Indicator] for the effect of their upstream supply chain on the environment." (page 63).

In the following Section (1.2) we provide the reader with a background for the concept of shared responsibility before we outline the purpose of this particular work (Section 1.3).

1.2. The concept of shared responsibility

It is perhaps because of the tendency of economic policy in market-driven economies not to interfere with consumers' preferences that the producer-centric representation is the dominant form of viewing the environmental impacts of industrial production. In statistics on energy, emissions, water etc, impacts are almost always presented as attributes of industries ('on-site' or 'direct' allocation) rather than as attributes of the life cycles of products for consumers. On a smaller scale, most existing schemes for corporate sustainability reporting include only impacts that arise out of operations controlled by the reporting company, and not life-cycle / supply-chain[6] impacts (WBCSD and WRI, 2004). According to this world view, "upstream and downstream [environmental] impacts are […] allocated to their immediate producers. The institutional setting and the different actors' spheres of influence are not reflected" (Spangenberg and Lorek, 2002, p.131).

On the other hand, a number of studies have highlighted that final consumption and affluence, especially in the industrialised world, are the main drivers for the level and growth of environmental pressure. Even though these studies provide a clear incentive for complementing producer-focused environmental policy with some consideration for consumption-related aspects, demand-side measures to environmental problems are rarely exploited (Princen, 1999, p.348).

The nexus created by the different views on impacts caused by industrial production is exemplified by several contributions to the discussion about producer versus consumer responsibility for greenhouse gas emissions (Munksgaard and Pedersen, 2001; Bastianoni et al., 2004; Lenzen et al., 2004; Munksgaard et al.,

[5] The tool has also been applied in a number of case studies: (Wiedmann and Lenzen, 2006a; Wiedmann and Lenzen, 2006b; Lenzen, 2007; Wiedmann et al., 2007).

[6] Note that the terms 'life-cycle' and 'supply chain' do not mean exactly the same (Seuring, 2004, contains a suggestion on how to distinguish between the two terms). For the purpose of this article we refer to 'life cycles' as life stages of a good or service (e.g. "cradle-to-gate" or "cradle-to-grave") and we use this term in context with methodologies such as LCA. When using 'supply chain' we explicitly refer to agents along an economic (supply) chain in order to demonstrate that businesses (people) are involved with their decisions, activities, etc.

in press). Emissions data are reported to the IPCC as contributions of producing industries located in a particular country (Task Force on National Greenhouse Gas Inventories, 1996) rather than as embodiments in products consumed by a particular population, irrespective of productive origin. However, especially for open economies, taking into account the greenhouse gases embodied in internationally traded commodities can have a considerable influence on national greenhouse gas balance sheets (e.g. Peters and Hertwich, 2006a; Wiedmann et al., 2007a). Assuming consumer responsibility, exports have to be subtracted from, and imports added to national greenhouse gas inventories.

Similarly, at the company level, "when adopting the concept of eco-efficiency and the scope of an environmental management system stated in for example ISO 14001, it is insufficient to merely report on the carbon dioxide emissions limited to the judicial borders of the company" (Cerin, 2002, p.59). "Companies must recognise their wider responsibility and manage the entire life-cycle of their products … Insisting on high environmental standards from suppliers and ensuring that raw materials are extracted or produced in an environmentally conscious way provides a start" (Welford, 1996). The need for capturing impacts across the entire upstream and downstream supply chain (the boundary problem) is of particular importance and has therefore been noted in the Guidelines of the Global Reporting Initiative (GRI) and by the World Business Council on Sustainable Development (Global Reporting Initiative, 2002; Global Reporting Initiative, 2005).

A life-cycle perspective is also taken in Extended Producer Responsibility (EPR) frameworks: "Producers of products should bear a significant degree of responsibility (physical and/or financial) not only for the environmental impacts of their products downstream from the treatment and disposal of their product, but also for their upstream activities inherent in the selection of materials and in the design of products" (OECD, 2001, p.21-22). "The major impetus for EPR came from northern European countries in the late 1980s and early 1990s, as they were facing severe landfill shortages. [… As a result,] EPR is generally applied to post-consumer wastes which place increasing physical and financial demands on municipal waste management" (EPA NSW, 2003, p.2-4).

As practical implementations of Extended Producer Responsibility various environmental management concepts have evolved that directly address the flow of material (and information) along life cycles or supply chains and thereby relate to inter-organisational management aspects. According to (Seuring, 2004) these include "industrial ecology (IE), life-cycle management, closed-loop supply chains, integrated chain management and green/environmental or sustainable supply chain management." Life-cycle wide management based on Triple Bottom Line accounting can be added to this list (Foran et al., 2005a).

The Chartered Institute of Purchasing and Supply UK have launched voluntary guidelines for environmental purchasing and recommends achieving seven goals (CIPS, 1999; CIPS, 2000; CIPS, 2002): (1) establishment of a business case to make environmental purchasing viable and part of day-to-day operations, (2) an understanding of the environmental issues affecting the organisation and its supply chain, (3) the development of a purchasing policy which addresses environmental issues, (4) environmental criteria for ranking suppliers, (5) improved communication with suppliers, (6) suitable methods for collecting relevant information, and (7) agreed targets for further environmental performance improvements.

Recently, a range of companies have implemented policies that are aimed at reducing CO_2 emissions or other environmental impacts from upstream suppliers. This is reflected in recent conferences on the subject of supply chain (carbon) impacts and management[7], case studies (e.g. Carbon Trust, 2006), Government guidelines (e.g. DEFRA, 2006, p.63) and developments in carbon footprint estimation methods (see e.g. the discussion in Wiedmann and Minx, in press).

7 E.g. 'ENDS Corporate Carbon Footprint Conference', London, April 2007; 'Carbon Footprint Supply Chain Summit', London, May 2007 ; 'Corporate Climate Response', London, May 2007; or 'Measuring and Reducing Corporate Carbon Across Your Product Lifecycle or Supply Chain Conference', Brussels, 2007.

On the downstream side of a supply chain, the concept of product stewardship "suggests that all parties with a role in designing, producing, selling or using a product are responsible for minimising the environmental impact of the product over its life" (McKerlie et al., 2006, p. 620). In practice, this "shared responsibility" extends beyond the producers and users of a product to include local governments and general taxpayers who incur the expense of managing products at their end-of-life as part of the residential waste stream. This shared approach does not clearly designate responsibility to any one party, diluting the impetus to advance waste prevention. Indeed, at present, most of extended-responsibility initiatives proceed in a more or less qualitative and ad-hoc, rather than quantitative and systematic way in selecting, screening, ranking or influencing other actors in their supply chain. In any case, credible ranking of suppliers and their sustainability impacts is only impossible if a robust and reproducible quantitative rating is at hand.

1.3. Purpose of this report

When thinking about environmental and wider sustainability impacts of producers and consumers, crucial questions arise such as: who is responsible for what, or: how is the responsibility to be shared, if at all? For example: Should a firm have to improve the eco-friendliness of its products, or is it up to the consumer to buy or not to buy? And further: should the firm be held responsible for only the downstream consequences of the use of its products, or – through its procurement decisions – also for the implications of its inputs from upstream suppliers? And if so, how far should the downstream and upstream spheres of responsibility extend? Similar questions can be phrased for the problem of deciding who takes the credits for job creation or successful abatement measures that involve producers and consumers: Who has the best knowledge of, or the most influence over how to increase social benefits or reduce adverse impacts associated with the transfer of a product from producer to consumer?

The underlying research question of this work is "how can corporate sustainability performance be quantified and compared in practice, whilst taking into account the responsibility sharing nature of trading (within and across supply chains) and avoiding double-counting of impacts?" This more technical question aims at finding a consistent and reproducible method by which sustainability (TBL) impacts can be assigned in a quantitative way to agents of trading transactions. In this contribution we therefore

- describe the analytical approach to measure the indirect impacts of a comprehensive Triple Bottom Line account of a producing entity,
- present a quantitative concept of shared responsibility as a solution to assigning responsibility to both producers and consumers, in a mutually exclusive and collectively exhaustive way, and
- demonstrate practical applications in examples of quantification of indirect impacts, supply chain contributions and shared responsibility.

The rest of the paper is organised as follows. Section 2 explains the methodology and provides further references for the reader interested in mathematical details. Section 3 introduces the concept of shared responsibility with a practical example and Section 4 presents and discusses the results of exemplary TBL life-cycle assessments. Section 5 concludes.

2. Methodology

2.1. Measuring all indirect impacts

In this study, the principle of the Triple Bottom Line (TBL) is assessed using input-output analysis (IOA). Input-output analysis is a top-down economic technique, which uses sectoral monetary transactions data to account for the complex interdependencies of industries in modern economies. The result of generalised input-output analyses is a $f \times n$ matrix of TBL factor multipliers, that is embodiments of f TBL indicators (such as exports, labour, energy, etc.) per unit of final demand of commodities produced by n industry sectors. A multiplier matrix **M** can be calculated from a $f \times n$ matrix **Q** containing the direct, sectoral TBL indicator scores (e.g. from national economic, social and environmental accounts), and from a $n \times n$ direct requirements matrix **A** according to

$$\mathbf{M} = \mathbf{Q}(\mathbf{I}-\mathbf{A})^{-1} \qquad \text{Eq. (1)}$$

where **I** is the $n \times n$ unity matrix. For many countries, the direct requirements matrix **A** can be compiled from the input-output tables published by the national statistical agencies.

The $f \times 1$ TBL inventory **F** of a given sectoral final demand represented by a $n \times 1$ commodity vector **y** is then simply

$$\mathbf{F} = \mathbf{M}\mathbf{y} \qquad \text{Eq. (2)}$$

An introduction into the input–output method and its application to environmental problems can be found in (Leontief and Ford, 1970; Proops, 1977; Miller and Blair, 1985; Lenzen, 2001).

Input-output theory was pioneered by Nobel Prize winning economist Wassily Leontief in the 1940s and applied by Herendeen and others (Herendeen, 1973; Herendeen, 1974; Herendeen and Sebald, 1975; Herendeen and Tanaka, 1976; Herendeen, 1978; Herendeen, 1981) to many energy analyses problems from the mid-1970s to today. It had always been Leontief's intention that IOA be extended from purely financial considerations to a range of social and physical elements (Leontief and Ford, 1970). However, such methods have not been widely employed in government planning and policy circles, except for the European NAMEA movement, in which physical tables are set up as satellite accounts to the National Accounts (de Haan and Keuning, 1996; de Haan, 1999; Stahmer, 2000; Statistisches Bundesamt, 2001). These physical accounts as well as our work aim at integrating the structure and function of the financial economy (as described by the national IO tables) with other national social and environmental accounts such as energy, greenhouse emissions, water, land use, employment and so on.

There is a well-known precedent for IOA techniques improving assessment processes: In life cycle assessment (LCA), which aims to calculate the total environmental burdens associated with a product, IOA has experienced a significant role in overcoming what is known as the boundary problem, or the problem of incompleteness of an LCA inventory due to the arbitrary truncation of the system by a subjectively set boundary (Suh et al., 2004), thus preventing decision-makers from overlooking important hidden upstream impacts.

In an empirical application the IO formalism was applied by researchers at the University of Sydney to compile a comprehensive TBL account of the Australian economy. National- and state-level economic sector level data for 344 sectors of the Australian economy were compiled, using input-output tables and additional data. A part of these accounts are published[8] and contain information on the aggregate and average performance of 135 economic sectors for ten TBL indicators together with their main data sources.[9] The synthesis of disparate data sources is a major component of the development of a generalised IOA framework.

The Australian TBL sector accounts also describe in hard numbers economic, social and environmental indicators against a common unit of one dollar of final demand. The latter constitutes a convenient and meaningful numeraire, because it is the destination of GDP, the common measure of national economic performance, and as Adam Smith concluded already in 1776, it is "the sole end and purpose of all production". Thus economic indicators of surplus, exports and imports can be reported as "dollars of surplus per dollar of final demand". Social indicators such as employment, wages and government revenue can be described as "the minutes of employment generated per dollar of final demand". Environmental indicators such as greenhouse gas emissions, water requirement and land disturbance can be described as "kilograms of carbon dioxide equivalent emissions per dollar of final demand" or the like. However, the presentation of such complex analyses is always fraught with the tension between simplicity and complexity.

2.2. Unravelling supply chains

The boundary within which an organisation accounts for its environmental, social and/or economic effects is usually defined as that over which the company has direct influence and can exercise control. However, such a definition faces a number of challenges. The level of influence and control will vary from organisation to organisation and from year to year, invalidating comparisons within and between organisations. Moreover, extending the boundary beyond the immediate control of the organisation still begs the question of exactly where to draw the line. Decisions will differ between organisations and over time. Establishing a clear boundary for an analysis that is consistent across all indicators seems at first sight to be almost impossible.

Notwithstanding these challenges, the boundary problem can be solved by taking a full life-cycle perspective and by taking into account the structure of the economic system as described in the national input-output tables. This structure is best depicted as an ever-expanding "tree of interdependence" that starts at a particular economic entity, and stretches across upstream production layers, containing sectors at different production stages linked together by supply chains. Thus a particular impact associated with a good or a service cascades from primary industries producing raw materials, via secondary (manufacturing) industries into the sector or company that delivers the final product to the consumer.

The general decomposition approach described in the following was introduced into economics and regional science in 1984 under the name ‘structural path analysis’ (Crama et al., 1984; Defourny and Thorbecke, 1984). In order to systematically determine environmentally important production chains, the total factor multipliers derived in Eq. (1) can be decomposed into contributions from all input paths, by ‘unravelling’ the Leontief inverse using a series expansion. A multiplier m_i for industry i can then be derived, representing the

8 http://www.isa.org.usyd.edu.au/publications/balance.shtml, see also (Foran et al., 2005a; Foran et al., 2005b).

9 The ten macro TBL indicators published were: primary energy, greenhouse gas emissions, water use, land disturbance, value of imports, value of exports, surplus, government revenue, employment (hours) and income. However, the extended data set features many more indicators than the published set: it also includes material flows, the Ecological Footprint, emissions of more than 100 toxic, ozone-depleting, acidifying and eutrophicating substances to air, water and soil, and two prominent Dutch LCA sets (the CML midpoint set and PRé’s endpoint Eco-indicator99). In total the whole database distinguishes 1270 indicators for 344 industry sectors (http://www.isa.org.usyd.edu.au/research/ISA_TBL_Indicators.pdf).

sum over a direct factor input q_i, occurring in industry i itself, and higher order input paths (for details see Lenzen, 2002; Lenzen, 2003).

Such a structural path analysis covers the entire upstream supply chain. It "unravels" a company's impacts into single contributing supply paths. It gives extensive detail of the impact of a sector's or company's activities. It allows investigating the location of impacts within the supply chain. In the case of a company, the control over the input procurement process then provides the possibility of substituting impact-intensive suppliers with more sustainable suppliers.

Detailed outputs derived from the application of structural path analysis include:

- a description of the path
- the path value (e.g. the greenhouse gas impact in grams of CO_2-equivalent per $ of final output of business management services),
- the path order (that is, from which upstream supply layer the path originates),
- the path coverage, that is, the relative contribution (in %) to the total TBL impact of the company.

3. Assigning responsibility along supply chains

3.1. Full producer and consumer responsibility

Traditional company environmental reports and national environmental statistics accounts are based on a producer responsibility perspective. Companies usually report on-site emissions to air and water and other direct impacts such as noise, waste, direct use of energy and resources etc (see e.g. DEFRA, 2006). With the same principles, the national Environmental Accounts are compiled, summing up all the emissions, resource use etc that can be directly attributed to specific industrial sectors (see e.g. ONS, 2007).

In the following example we compare this production based approach with the consumption based perspective taken in LCA. Consider the carbon dioxide emissions caused by one particular economic chain: the production and consumption of glass containers and their food contents. This is a purely illustrative example with fictitious numbers and for the sake of simplicity we assume that the participants of this economic chain do not supply anyone other than their successor. According to the traditional perspective of producer responsibility accounting, we note down the direct (on-site) emissions of each member of the supply chain (Figure 1 and Table 1). The final consumer does not emit CO_2 in this particular process and therefore gets no emissions attributed.

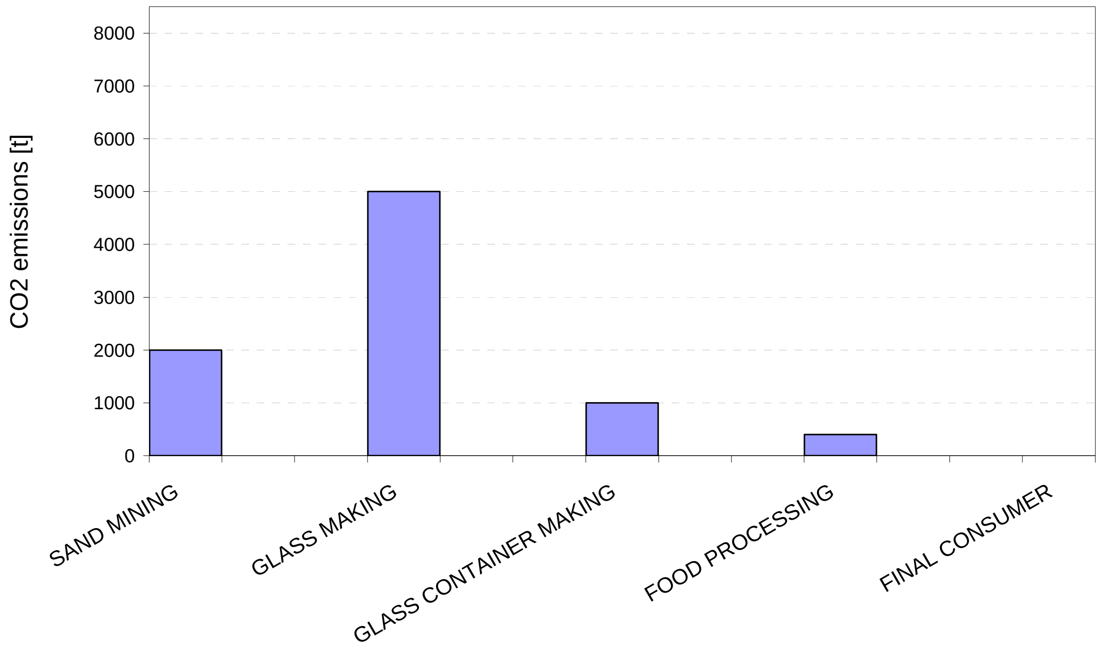

Figure 1: Example for a full producer responsibility account of direct CO_2 emissions along a supply chain.

Note that there would be double-counting if the producers of glass, containers and food used traditional LCA to calculate and publicise their CO_2 emissions. This is because the full 'life cycle' from 'cradle-to-gate' would be taken into account. The emissions caused by the sand miner, the glass maker and the glass container maker would appear in the food company's CO_2 emission account as they are all suppliers. Hence the 'embodied' CO_2 emissions of this final production stage, derived by traditional LCA, would be 8400 t. It is hence multiple-counted.

LCA is a method that assumes full consumer responsibility. In life-cycle thinking, the consumer is placed at the very end of the supply chain. All impacts incurred during production are heaped onto the consumer of products. Therefore, if double-counting is to be avoided, LCA can only be used for the final consumers in an economy: the impacts of any producer must be zero.[10] This is a full consumer responsibility account as depicted in Figure 2.

[10] This is also the perspective taken by traditional Ecological Footprint estimates such as the National Footprint Accounts (e.g. Lenzen and Murray, 2003; Wackernagel et al., 2005; Wiedmann et al., 2006; WWF et al., 2006).

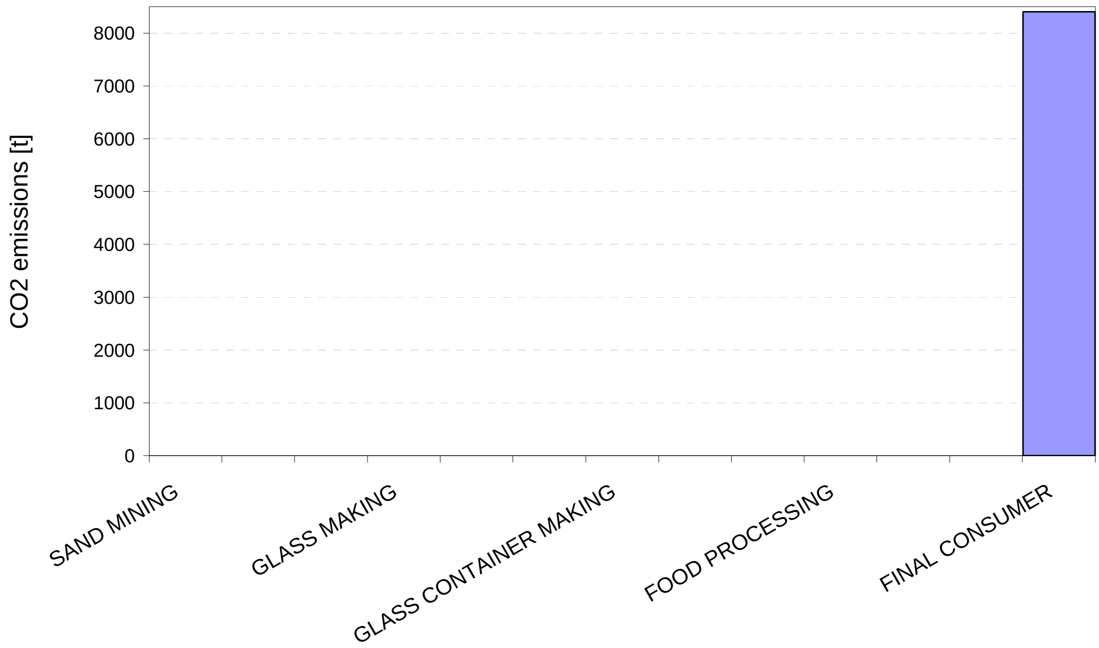

Figure 2: Example for a full consumer responsibility account of all CO_2 emissions along a supply chain.

A particular disadvantage of full producer or consumer responsibility is that neither allows for both producers and consumers to evaluate their TBL impacts without double-counting. Full producer and consumer responsibility therefore appear somewhat unrealistic in their extremeness. Both producers and consumers wish to report their respective part of the impact, and it is intuitively clear that responsibility is somehow to be shared between the supplier and the recipient of a commodity, because the supplier has caused the impacts directly, but the recipient has demanded that the supplier do so.

3.2. Quantifying responsibility shares

As with many other allocation problems, an acceptable consensus probably lies somewhere between producer and consumer responsibility. In order to assign responsibility to actors participating in these transactions, one has to know the respective supply chains or inter-industry relations. Hence, a problem poses itself in form of the question: "How can one devise an accounting method that allows apportioning environmental (or other TBL) impacts to both producers and consumers while avoiding double-counting?" This problem has been addressed in two recent publications (Gallego and Lenzen, 2005; Lenzen et al., 2007).

The result is that in reality, both the final consumers and their upstream suppliers play some role in causing environmental impacts: The suppliers use resources and energy in order to produce, and make decisions on how much and what type of resources and energy they use. Consumers decide to spend their money on products coming from those upstream suppliers. And this role-sharing probably holds for many more situations in business and in life. The concept of shared responsibility recognises that there are always two (groups of) people who play a role in commodities produced and impacts caused, and two perspectives involved in every transaction: the supplier’s and the recipient’s. Hence, responsibility for impacts can be shared between them. Naturally, this applies to both benefits and burdens, and therefore to all positive and negative TBL indicators.

The idea of shared responsibility is not new. However, shared responsibility has only recently been consistently and quantitatively conceptualised by Gallego and Lenzen (2005).[11]

Sharing impacts between each pair of subsequent supply chain stages gets rid of the double-counting problem described above. One question that remained unresolved in the exposition by Gallego and Lenzen (2005) was in which proportion impacts should be shared between supplier and recipient in an economic chain. One possibility could be a 50%-50% split, where 50% of an on-site impact is retained by the producer and 50% is passed on to the producer's downstream client. However, as outlined in Lenzen et al. (2007), a 50%-50% share leads to a methodological inconsistency: the part of the impact that is passed on and eventually reaches the final consumer is dependent on the number of participants in a supply chain. This dependence of responsibility allocations on the vertical integration of sectors is inconsistent and undesirable, because it creates incentives for de-merging in reporting practice.

A solution to this problem, as suggested by Lenzen et al. (2007)[12], is to peg the percentage split of responsibility retained by the supplier ($1-\alpha$) to a quantity that is independent of sector classification. Value added is such a quantity: No matter whether a supply chain is represented as many or few stages, total value added is always the same at the end of the chain. Lenzen et al. (2007) therefore propose to use

$$1-\alpha_{ij} = \frac{v_i}{x_i - T_{ii}} \qquad \text{Eq. (3)}$$

where v_i is value added of industry sector i, and x_i-T_{ii} is gross output minus intra-industry transactions, in other words net output. Intra-industry transactions T_{ii} have to be understood as transactions between different branches of the same industry sector.

Using the supply chain from above, we apply Eq. (3) with example values for value added (VA) and net output (NO) for each supplier as shown in Table 1.

Table 1: Quantitative example of allocating CO_2 emissions in a (hypothetical) supply chain by applying the shared responsibility approach described in Lenzen et al. (2007).

	SAND MINING	GLASS MAKING	GLASS CONTAINER MAKING	FOOD PROCESSING	FINAL CONSUMER
Value added (VA) [m$]	0.4	1.6	2.1	16.0	
Net output (NO) [m$]	1.6	3.2	5.3	21.3	
$1-\alpha$ = VA/NO	0.25	0.50	0.40	0.75	
Responsibility share	25% (retained)-75% (passed on)	50% (retained)-50% (passed on)	40% (retained)-60% (passed on)	75% (retained)-25% (passed on)	
On-site CO_2 emissions [t]	2000	5000	1000	400	
CO_2 received [t]		1500	3250	2550	738
CO_2 retained [t]	500	3250	1700	2213	738
CO_2 passed on [t]	1500	3250	2550	738	

[11] See also (Rodrigues et al., 2006) for the definition of an indicator of environmental responsibility that accounts for transactions between countries in a 'fair' manner and Lenzen et al. (2007) for a discussion.

[12] See also (Lenzen, in press; Lenzen, submitted).

Assume the sand mine supplies 1.6 million $ worth of sand to the glass maker, to which the latter adds m$1.6 of value to produce m$3.2 worth of glass net output. To this, the glass container manufacturer adds m$2.1 of value, producing m$5.3 worth of glass containers. To this, the food manufacturer adds m$16 of value, producing m$21.3 worth of food.

The sand mine adds 25% of value to sandstone by turning it into sand. It will hence retain a shared responsibility of 25% of their CO_2 emissions (500 t of 2000 t) and send the remaining 75% (1500 t) down the supply chain to the glass manufacturer. The glass maker will add 50% of value to sand by turning it into glass. The glass maker is hence assigned 50% of 1500 tonnes of CO_2 passed down from sand, plus 50% of 5000 tonnes used while manufacturing glass. The remainder (3250 t) is passed on to glass containers. The glass container manufacturer will add 40% of value to glass, and is thus assigned 40% of the emissions embodied in glass containers, and so on. Finally, the food manufacturer adds 75% of value to glass containers, and is therefore assigned 75% of emissions embodied in packed food. Final consumers (households, the government) are at the end of the supply chain, and receive the remainder (738 t of CO_2). This process of sharing responsibility by using a VA/NO allocation is depicted in Figure 3; the final results are shown in Figure 4.

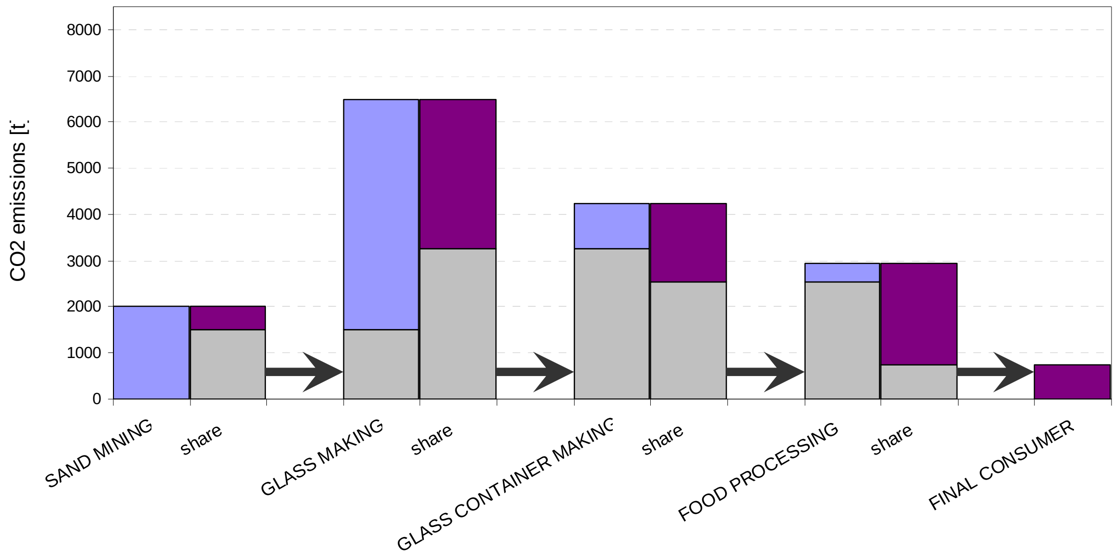

Figure 3: Process of applying shared, value-added-allocated responsibility to CO_2 emissions in one particular supply chain (blue columns = on-site impact; grey columns = share that is passed on from one supplier to the next; purple columns = retained impact)

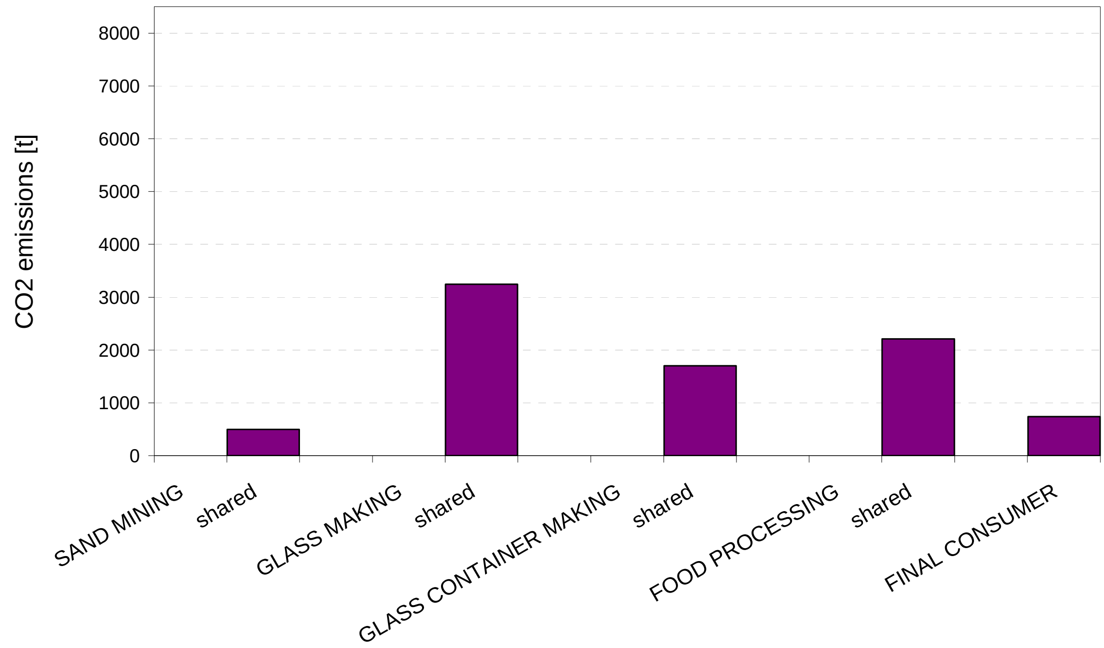

Figure 4: Results of applying shared, value-added-allocated responsibility to CO_2 emissions in one particular supply chain (identical to purple columns in Figure 3).

The logic of this allocation scheme (as opposed to a 50%-50% split) is that an organisation that controls its production to a high extent, retains a high share of the responsibility for the emissions. High control, or influence over the product can be approximated by high value added: Production processes that add a high percentage of value onto inputs usually transform these to a high extent, while low-value adding entities operate more like an "agent" of their inputs.

4. Example analyses

At the University of Sydney, TBL accounting has been formulated as a quantitative framework using an input-output-based LCA method. This framework has been applied to dozens of organisations in reporting on their sustainability performance – companies, government departments, NGOs.[13] Experiences were collected in a 3-year pilot project. It became clear that the data collection burden for the organisation has to be as small as possible. As a result, a software tool was developed in collaboration with the using organisations, enabling users to create a comprehensive sustainability report solely by importing their existing financial accounts. This software tool is called Bottomline^3, or short BL^3 ("BL-cubed").[14]

The model framework is described in (Foran et al., 2005b) with a summary available in (Foran et al., 2005a). A short summary of the methodology can also be found in (Wiedmann and Lenzen, 2006a). The IOA and TBL framework of BL^3 can be adapted to any economy with adequate data from economic and environmental accounts. The UK version of Bottomline^3, for example, is based on a static, single-region, open, basic-price, 76-sector industry-by-industry input-output model of the UK economy, augmented with a

13 http://www.isa.org.usyd.edu.au/research/tbl.shtml

14 http://www.bottomline3.com and http://www.bottomline3.co.uk.

database of environmental, social and economic indicators. The TBL indicator set of BL[3] UK features a number of economic, social and environmental indicators, including greenhouse gases; toxic, ozone-creating, acidifying and eutrophicating air pollutants; heavy metals; energy and resource use; the Ecological Footprint; and material flows. In total the whole database distinguishes well over 100 indicators. Financial transaction data are derived from UK National Accounts Supply and Use Tables (Wiedmann et al., 2006; ONS, 2006a), employment data are from the UK Annual Business Inquiry[15], sectoral emission and resource use data are from UK Environmental Accounts (ONS, 2007), material flow data from (SEI et al., 2006) and Ecological Footprint data per sector were derived by using the method described in (Wiedmann et al., 2006).

Two types of input data from the organisation under investigation are required for the calculation of TBL impacts with Bottomline**[3]**, financial accounts and on-site impact data. Financial accounts include all expenditure and revenue data from one year, ideally as detailed as possible. This consists of all financial transactions required to operate the business, from purchasing of materials, goods and services through to financing and insuring. On-site data include fuel, land and resources directly used by the company, e.g. the consumption of fossil fuels needed for processing, heating and driving or direct (on-site) appropriation of built land. For the indicator 'employment', the 'on-site impact' is the number people directly employed by the company. On-site impact data should be in physical units (e.g. kilowatt-hours or litres of fuels or hectares of built land).

Software outputs include aggregate figures, detailed breakdowns, sector benchmarking and rankings of indicators into supply chain contributions. As an example of how results from a TBL analysis with BL**[3]** look like we show four results for a hypothetical food company in the following graphs (note that this example is different from the one in Section 3.2 as we now look at a wider range of TBL impacts, not just CO_2 emissions, and at all possible supply paths to the food company, not just the one delivering glass containers).

TBL impacts of the food company can be compared in a meaningful way with other enterprises in the same sector if they are normalised to the business size. This can be done by dividing the absolute impact (e.g. tonnes of CO_2 emitted) by the company's total expenditure in the same time period (normally one financial year). For benchmarking purposes the resulting impact intensities (e.g. in t CO_2 / $) can be directly compared to those from the sector-average. All necessary sector benchmark data are derived directly from the national data inherent in the BL**[3]** tool. Depicted in a spider diagram, the ratios of business to sector intensities then elegantly convey an overview of the business' TBL performance on a number of economic, social, and environmental indicators in one visual representation. The ratios divide business intensity by sector intensity for indicators that are deemed negative ("less is good", e.g. CO_2 emissions), so that better performance leads to lower ratios. For indicators that are deemed positive ("more is good", e.g. employment), these ratios are inversed, so that better performance leads to lower ratios.[16] The TBL spider diagram is hence – within limits – interpretable as "dents are good, spikes are bad". An example spider diagram is shown in Figure 5.

[15] http://www.statistics.gov.uk/abi/whole_econ.asp

[16] A similar representation is proposed by (Krajnc and Glavic, 2005, p.561). In their diagram, however, a larger 'amoeba' indicates a higher "probability of sustainable development".

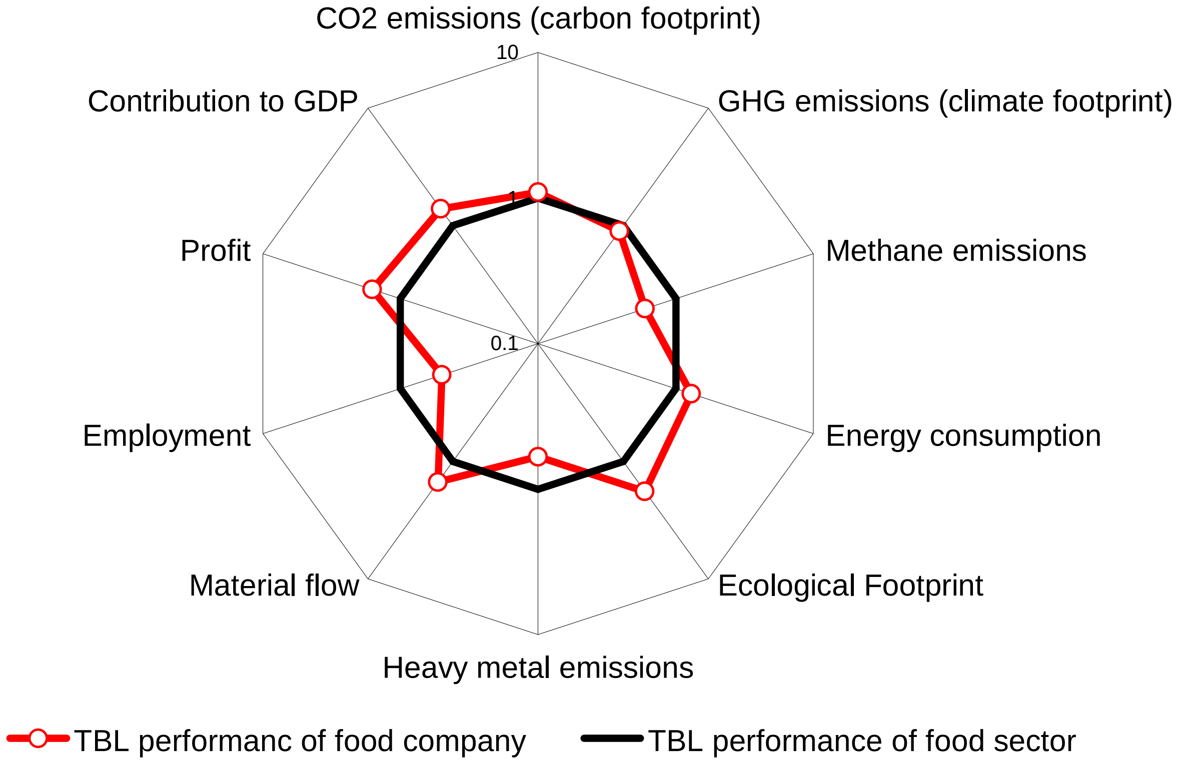

Figure 5: A spider diagram presentation of Triple Bottom Line performance of an example (food) company in key financial, social and environmental indicators (red line). The central, regular polygon in the centre of the diagram (thick black line) shows the average TBL performance of the economy-wide food sector, allowing a benchmark comparison between the company and its sector. Indicators with above average performance are closer to the centre, while below average indicators are positioned closer to the outside boundary, i.e. the centre locates ten-times-better performance (not ten-times-lower), the outer rim ten-times-worse performance (not ten-times-higher) (for an explanation of TBL indicators see (Foran et al., 2005b).

Figure 6 shows an example software output of the total material flows[17] that are needed to sustain the operations of an example company. Similar to the procedure explained in Section 3.2, the total impact (which is the sum of on-site plus indirect impacts embodied in upstream production) is divided into one part that is retained by the company and another part that is passed on further down the supply chain. BL^3 breaks down further the latter part and distinguishes two recipients of impacts, the final consumer and other businesses to which the company sells its products.

[17] For an explanation of this indicator see e.g. (Eurostat, 2001; National Academy of Sciences, 2004).

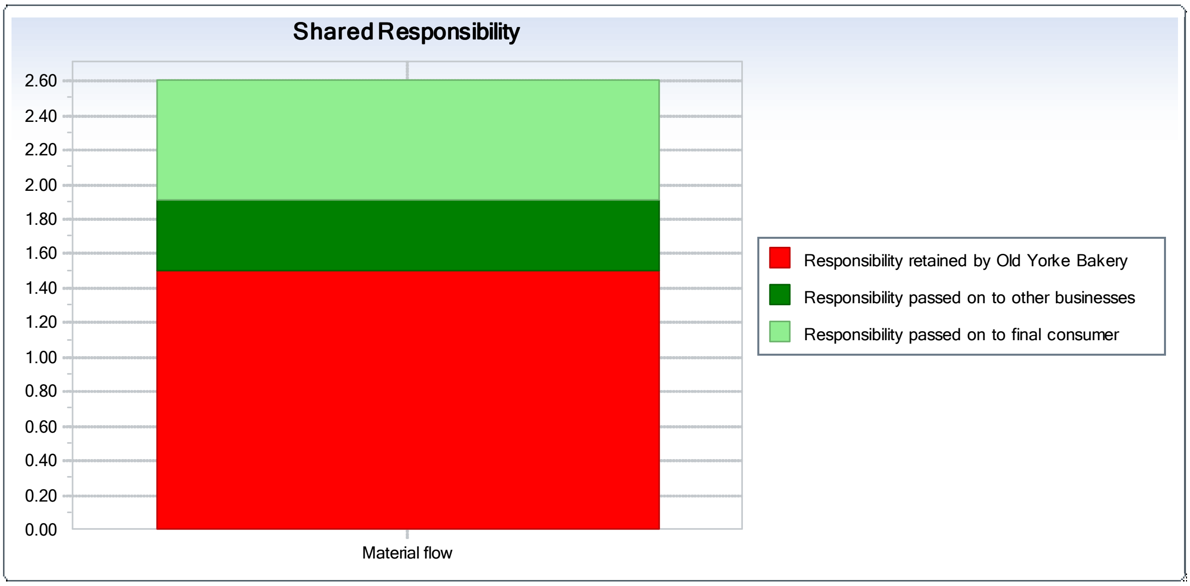

Figure 6: Responsibility shares of the material flow impact of an example (food) company. 1.5 kt (kilotonnes) of the total impact of 2.6 kt are retained by the company whereas 1.1 kt are passed on further down the supply chain (0.4 kt to other businesses and 0.7 kt to final consumers).

An analytical technique called Production Layer Decomposition shows whether overall impacts are caused directly by suppliers to the business (proximate effects), or indirectly by suppliers of suppliers (remote, supply-chain effects). This is depicted for a hypothetical carbon footprint analysis of a food company in Figure 7. On-site impacts (layer 1, showing direct emissions from the company itself) amount to around 50 t CO_2-eq. and are allocated to the 'Food' category, because our example company is part of this category. Amongst the company's direct suppliers (layer 2), major emitters are within Agriculture, Fuels (refineries and distribution), and Transport & communication. At layer 3, suppliers of suppliers to the company enter the picture: Amongst them are for example service providers. One example for a contribution from layer 3 would be a sand mine supplying sand to a glass company making bottles for the food company (our previous example from Section 3.2). Towards higher-order layers, contributions to the total carbon footprint become smaller and smaller and the total impact eventually saturates at around 220 t CO_2-eq.

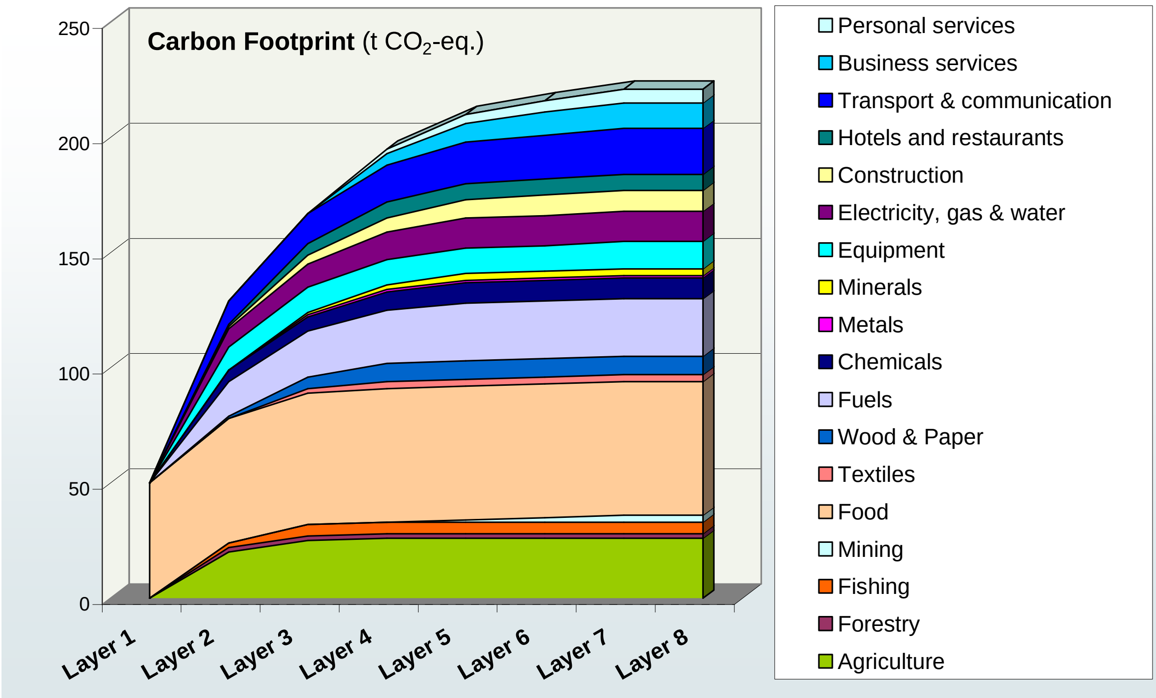

Figure 7: An example production layer diagram showing the direct and indirect carbon footprint (CF) as well as its origin for a (fictitious) food company. 'Layer 1' stands for the company itself, i.e. it shows its direct CF caused by direct emissions from heating and driving. 'Layer 2' represents the "suppliers" to the company, 'Layer 3' the "suppliers of the suppliers" and so on. In other words, Layers 2 to 8 show the indirect CF that is embodied in the products and services purchased by the food company. In this example, main contributors to the indirect CF are Agriculture, Fuels, and Transport & communication. This diagram looks different for each TBL indicator.

Finally, a Structural Path Analysis unravels the entire TBL impact into single paths, that make up the supply-chain system like branches make up a tree. It is the most detailed representation of a business' supply chain impacts. Table 2 shows the twenty most important paths that contribute to the total Ecological Footprint[18] of a hypothetical food company. On-site impacts make up about half of the total Ecological Footprint due to the consumption of fossil fuels.

Table 2: Results of a BL[3] structural path analysis of the Ecological Footprint of an example (food) company. The total Ecological Footprint embodied in the supplies from upstream producers is broken down into contributions from the supplying sectors (gha = global hectares). The list shows path values and orders (i.e. how large and how far away the impacts are)

Rank	Path Description	Path Value	Path Order	Percentage in total impact
1	Company (on-site impacts)	29.6 gha	1	51.2 %
2	Electricity > Company	6.70 gha	2	11.6 %
3	Agriculture > Company	4.85 gha	2	8.41 %
4	Food and drink > Company	3.52 gha	2	6.10 %
5	Pulp and paper > Company	1.97 gha	2	3.41 %

[18] For background information on this indicator see e.g. (Wiedmann et al., 2006).

Rank	Path Description	Path Value	Path Order	Percentage in total impact
6	Electrical machinery and equipment > Company	1.09 gha	2	1.88 %
7	Agriculture > Food and drink > Company	0.69 gha	3	1.19 %
8	Pulp and paper > Pulp and paper > Company	0.48 gha	3	0.83 %
9	Gas distribution > Company	0.46 gha	2	0.79 %
10	Electricity > Food and drink > Company	0.38 gha	3	0.67 %
11	Fishing > Food and drink > Company	0.37 gha	3	0.65 %
12	Iron and steel > Electrical machinery and equipment > Company	0.37 gha	3	0.65 %
13	Pulp and paper > Food and drink > Company	0.34 gha	3	0.59 %
14	Electricity > Gas distribution > Company	0.32 gha	3	0.56 %
15	Oil and gas extraction > Gas distribution > Company	0.27 gha	3	0.46 %
16	Non-ferrous metals > Electrical machinery and equipment > Company	0.26 gha	3	0.45 %
17	Food and drink > Food and drink > Company	0.26 gha	3	0.45 %
18	Plastic products > Food and drink > Company	0.24 gha	3	0.41 %
19	Electricity > Electrical machinery and equipment > Company	0.22 gha	3	0.39 %
20	Electricity > Electricity > Company	0.21 gha	3	0.36 %

These four examples show outputs that allow to determine

- which of the operating inputs embody the largest impacts,
- whether these impacts occur at direct suppliers, or at more remote supply chain locations,
- and which single input paths carry the largest impacts (through structural path analysis).

Especially the latter information is very helpful in informing organisational planning and priority setting for action towards financial, social and environmental sustainability. The results show whether addressing proximate impacts from the own company or from direct suppliers reaps more or less benefits than addressing more distant supply-chain impacts, e.g. through procurement decisions.

5. Conclusions

The methodology and the tool described in this work was developed to address a lack of accurate quantification and comparability of impacts in corporate sustainability reporting. We are able to allocate TBL loadings amongst the actors of economic chains, including all producers and consumers of commodities, in a mutually exclusive and collectively exhaustive way, that is without double-counting of any impacts. As a result we introduce the concept of shared responsibility to the overarching theme of corporate responsibility and demonstrate with practical examples its applicability.

The main differences between the principle of shared responsibility, and that of either full producer or full consumer responsibility are:

- In contrast to full producer responsibility, in shared responsibility, every member of the supply chain is affected by their upstream supplier and in turn affects their downstream recipient, hence it is in all actors' interest to enter into a dialogue about what to do to improve supply chain performance. There is no incentive for such a dialogue in full producer responsibility. In shared responsibility, producers are not alone in addressing the issue of TBL impacts, because their downstream customers play a role, too.

- In contrast to full consumer responsibility, shared responsibility provides an incentive for producers and consumers to enter into a dialogue about what to do to improve the profile of consumer products. It gives consumers information about where the impacts occur that are embodied in the products they buy.

It is important to harmonise this analytical approach, with its strengths of integration and lack of boundaries, with international approaches rapidly gaining headway such as ‘The Global Reporting Initiative’ and ‘The Equator Principles’. These approaches have widespread support through many globalised companies and national governments. However they are currently orientated to a ‘within the factory fence’ approach, but do acknowledge a number of higher order issues such as the origin of water and energy, and the labour practices used to supply intermediate inputs to production. Part of the harmonisation process will require the development of indicator datasets that match the requirements of these initiatives, as well as collaborating in the development of international software tools that enable the fluent use of whole economy accounting without boundaries.

The presented approach answers the research question posed at the beginning. It is science-based, consistent and robust. It uses regularly published, publicly available National Accounts data. It ensures that the real bottom line is quantified, not a figure determined by an arbitrary cut-off point that could be different in different organisations. Reporting on the real bottom line can deliver the full benefits of TBL reporting, including: the ability to make comparisons within and between organisations; completely transparent communication of an organisation’s impacts to all stakeholders; and detailed information across the whole supply chain as a basis for strategic decision making, e.g. environmental purchasing policies.

Numerate Triple Bottom Line accounting at the company level highlights a number of key issues important to the sustainable development agenda. Especially if all upstream impacts stemming from a web of supply chains are taken into account, new insights and useful information for corporate decision-making can be gained. The TBL accounting framework presented in this work increases abatement options, enables meaningful benchmarking, avoids loopholes in reporting and informs about real risk.

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