A Triple Bottom Line Approach for Measuring Supply Chains Sustainability Using Data Envelopment Analysis

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Abstract
This paper deals with the issues faced by those who endeavor in measuring sustainability in supply chains (SC) by using a comprehensive approach. Elkington´s Triple Bottom Line (TBL) divide sustainability in three aspects: environmental (E), economic and social (E2S). Firms publish their business (including SC) sustainability impacts through Corporate Social Responsibility reports (CSR). According to Global Reporting Initiative (GRI), a CSR framework, reported information should be sufficiently accurate/detailed towards performance, but reports are rather qualitative. Fast fashion (FF) is a recent phenomenon of production/promotion of cheap/readily disposable clothes. Data Envelopment Analysis (DEA) is the adequate tool to identify best practices regarding sustainability (multidimensional) and supply chains in FF. To allow comparability and tackle lack of quantitative data, TBL clusters (output) are proposed: for each Disclosure, a three layers scoring scale: absence (1), qualitative only (2), 2nd layer plus quantitative (4). This work´s main contribution is the use of DEA as a powerful tool to measure sustainability in SC and the TBL clusters link all dimensions in an innovative way.

Keywords: Data Envelopment Analysis, Sustainability, Supply Chains, Triple Bottom Line, Fast Fashion

1. Introduction

Supply chains (SC) are the main gateway to Sustainability. The article focus will be on measuring the performance of supply chains against sustainability disclosures in Corporate Social Responsibility (CSR) reports with Global Reporting Initiative (GRI) framework. The GRI framework uses the Triple Bottom Line (TBL) approach for addressing Sustainability. TBL is a multidimensional form to structure environmental, economic and social concerns.

The paper will analyze the textile and apparel sector (fast fashion), comparing performance using Data Envelopment Analysis (DEA). Comparability (benchmarking) between reports will be allowed by using a scale for qualitative and quantitative data to address the TBL. Therefore, the benchmarking process will be undertaken by using inputs/outputs out of economic data and by the scores given by CSR reports analysis.

One definition for Sustainable Supply Chain Management (SSCM) is, according to Seuring & Müller (2008), the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development (triple bottom line – TBL). Considering integration of sustainability into supply chain management (SCM) an ever increasing matter, "how to measure supply chain wide sustainability performance is paramount" (Seuring & Gold, 2013).

Multi-criteria decision making (MCDM) techniques, in the analytical models, and

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mathematical programming models (e.g. multi objective technique) are the most often chosen model types for SSCM assessment (Brandenburg, Govindan, Sarkis, & Seuring, 2014). DEA is a technique located in the confluence of analytical and mathematical programming models. So far, there is no research that uses DEA for measuring sustainability in supply chains, accounting for the three dimensions simultaneously, with data out of CSR reports, using the GRI G4 framework.

Comparability between reports is not straightforward. To overcome uneven reports´ constraint, a scale was built considering a layer-scoring system for quantitative and qualitative data. Therefore, the sum of scores for socio-economic and environmental dimensions will be used, along with financial data, as DEA input/outputs.

The main contributions of this article are: delving into the GRI G4 disclosures and extracting their essence; considering all the TBL dimensions at the same time for measurement; assessing supply chain for sustainability matters using real world data; somehow bridging the gap between CSR reports to allow comparability; although in an indirect fashion (by proxy) and with limited boundaries (tier 1), supply chains are being measured; comparability provided by the scale and the sum of scores of socio-economic and environmental; the insight of disclosures from a layer standpoint (layer 1 through 3); applying DEA for measuring sustainability (via TBL) in a comprehensive way, by including all dimensions in the analysis (non-financial) along with financial data in the model.

The remainder of this article is structured as follows: Section 2 (Literature Review), Section 3 (Methods), Section 4 (Results), Section 5 (Discussion), and Section 6 (Conclusion).

2. Literature Review

Considering sustainability, economic, environmental and social factors needs to be leading companies' supplier selection agenda (Bai & Sarkis, 2010). Thus, beyond the economic dimension, integration of environmental and social criteria is mandatory regarding performance objectives for single companies along with the management of the whole supply chain (Bai & Sarkis, 2010). The apparel and textile industry with its prevalence of social issues (e.g. underpaid workers, unsafe working conditions) would be a major consideration for social sustainability issues.

There is a demand for further investigation on Operational Research (OR) applications and hybrid qualitative and quantitative approaches (Min & Kim, 2012). Performance measures and metrics including financial and non-financial, and tangibles and intangibles assist companies to make more informed decisions (Gunasekaran & Gallear, 2012). McElroy & van Engelen (2012) propose the analysis of metrics published and used by corporations in the measurement of their supply chains sustainability (CSR reports) as an avenue of future research.

Brandenburg et al. (2014) summarize the modeling approaches in SSCM linking model type (keywords) to a multitude of tools and techniques and employed solution method. The possibility to handle multiple objectives is a plausible explanation of the popularity and numerous applications of modern benchmarking techniques. The nonparametric DEA approach provide particular strengths with peers providing useful and appropriate

information for performance improvement targets and decompositions of the overall efficiency that can elicit more specific means to improve efficiency (e.g. to change the scale of operation) (Bogetoft & Otto, 2011).

Callens and Tyteca (1999) points to DEA in sustainability assessment declaring that "efficiency with respect to economic, social, and environmental resources is viewed as a necessary (but not sufficient) step towards sustainability". DEA also identify units that reveal best practice in terms of sustainability. (Gerdessen & Pascucci, 2013) and can be applied to measure sustainable business development, including numerous costs and benefits (both tangibles and intangibles as well as financial and non-financial) (Gunasekaran & Gallear, 2012).

McElroy & van Engelen (2012) affirm that the deliberate incorporation of context in sustainability measurement, management and reporting makes it possible to determine whether or not behaviors are sustainable in the first place. GRI endorses that information on performance should be placed in context at the sector, local, regional, or global level (e.g. G4-EN9 – Water sources significantly affected by withdrawal of water) (GRI, 2013). McElroy & van Engelen (2012) compares a report´s absence of context to a financial reporting with income statements routinely prepared with no mention to costs at all.

The fast fashion industry has a highly cost-driven competitive structure, always offering the next new trend to the customers (Christopher, Lowson, & Peck, 2004), with high order fulfilment rates for customer demand at its peak points (Barnes & Lea-Greenwood, 2006). Therefore, responsiveness to demand is achieved through supply chain related strategies like just-in-time sourcing (Bruce, Daly, & Towers, 2004) and agile SCM (Bruce et al., 2004). Although, this comes at a cost, breeding unsustainable behavior like various ethical (Barnes & Lea-Greenwood, 2006) and environmental issues (Saicheua, Knox, & Cooper, 2012).

3. Methods

Communicating CSR attitudes is inevitably associated with responsible behavior or having some social responsibility facts (and acts) to disclose (Fernandez-Feijoo, Romero, & Ruiz, 2014). In addition, the company is setting a positive example for other businesses to follow (European Commission, 2005). Hence, sustainability is considered a key dimension of corporate social responsibility (CSR) (Pagell, Krause, & Klassen, 2008). Reporting practices in CSR are deemed as a proxy for sustainability behavior (Nielsen & Thomsen, 2007). Hence, researches based on measurements of actual sustainability performance can further the discussion in the literature (Palenberg, Reinicke, & Witte, 2006).

Out of more than 40 potential firms that could have possibly issued CSR reports related to fast fashion brands, the reasonable sample for running the model were ten reports. The term brands are herein used in a broad sense given that sustainability reports are provided as a bundle, including the brands of the group´s portfolio (e.g. Inditex group – Bershka, Pull & Bear, Zara). The model intends to be a reasonably applied decision-making tool using data out of public available CSR reports.

Global Reporting Initiative (GRI) has long been widely recognized as the most reliable

framework for disclosing information regarding sustainability (Kaye, 2011; Nikolaeva & Bicho, 2011). The Principles for Defining Report Content describe the process of reporting considering the organization's activities, impacts, and stakeholders expectations and interests (e.g. Sustainability Context). The Principles for Defining Report Quality guide choices on ensuring the quality of information in the sustainability report, including its proper presentation (e.g. Comparability and Accuracy).

Information for each identified material Aspect can be reported as Disclosures on Management Approach (DMA) and/or Indicator (GRI, 2013). Indicators yield information on the economic, environmental and social performance or impacts of the relationship organization – material Aspects. The DMA gives an opportunity to explain how economic, environmental and social impacts (in relation to material Aspects) are managed and delivers narrative information on how an organization identifies, assess, and responds (proactive vs. reactive) to its actual and potential material TBL.

A model was devised for building/selecting outputs and inputs that would take into account the sector characteristics, DEA assumptions and G4 Disclosures (General, Specific, and DMA). DMA is frequently overlooked in the literature. There is a complimentary condition between the Indicators and DMAs. For management use, when firms intend to disclosure their sustainability accomplishments, a mandatory condition is to couple Indicators with DMAs at some level.

Two output TBL clusters were conceived as a means of dealing with the great number of Disclosures vs. number of DMUs, and to permit comparability among quantitative data achieved with different methodologies/assumptions. Besides the quantitative data, there is quite a deal of qualitative data that necessarily would need some kind of transformation into quantitative to fit in the model. The cluster is a technique to normalize the data to allow comparability and overcome the high number of disclosures issue, to minimally capture all dimensions of sustainability in a firm´s supply chain.

The TBL clusters grouped G4 Disclosures in Socio-economic (E2S) and Environmental (E). Four environmental (E) and four Socio-economic (E2S) Disclosures are submitted to the scoring system twice. The double appearance of the eight Disclosures are DMA- and upstream/downstream-related modeling. The distribution of Disclosures inside the clusters are shown in Table 1.

Table 1: Disclosures´ Distribution (Input, TBL Clusters Output (E2S,E), Output)

Factor	Input (Fin)	TBL Output Cluster (E2S)	TBL Output Cluster (E)	Output (Fin)
Scale (organization)	G4-9 (cost of sales)			G4-9 (net sales)
Training		G4-LA9, G4-HR2, G4-SO4, G4-56		
Water			G4-EN8, G4-EN9, G4-EN10	
Operations / Supplier		G4-LA14, G4-HR10, G4-SO9, G4-SO1, G4-SO2, G4-EC9, G4-HR4, G4-HR5, G4-HR6, G4-6, G4-12, G4-LA15 (DMA), G4-HR11 (DMA), G4-SO10 (DMA),	G4-EN32, G4-EN33, G4-EN33 (DMA),	
Governance		G4-37, G4-42, G4-45		

Factor	Input (Fin)	TBL Output Cluster (E2S)	TBL Output Cluster (E)	Output (Fin)
Energy			G4-EN3, G4-EN4	
Water/Waste			G4-EN22, G4-EN23, G4-EN27 (u), G4-EN27 (d)	
Transportation			G4-EN30 (u), G4-EN30 (d)	
Environmental Protection			G4-EN31 (u), G4-EN31 (d)	
Customer		G4-PR1, G4-PR1 (DMA), G4-PR2, G4-PR3, G4-PR4		
Material Aspects / Boundaries		G4-19, G4-21		
Community Investments		G4-EC1, G4-EC7, G4-EC8		
Greenhouse Gases (GHG)			G4-EN15, G4-EN16, G4-EN17	
Stakeholder Engagement		G4-24, G4-25, G4-27		
Financial (Fin); upstream (u), downstream (d)				

Benchmarking TBL reports using a scoring system possibly yield potential benefits (Skouloudis, Evangelinos, & Kourmousis, 2009). The TBL input/output clusters will take the following scoring system: **first layer**, the G4 GRI Disclosure is not addressed in the report or addressed with data that is not concerned with the Indicator/DMA (**1 point**); **second layer**, the G4 Disclosure is addressed with some sort of information, rather qualitative data, or because the Indicator/DMA only requires this kind of data (**2 points**); **third layer**, the level of data from the second layer plus quantitative data, sometimes coupled with methodologies and assumptions (**4 points**).

4. Results

Performing a Data Envelopment Analysis (DEA), under the technology assumption of Variable Returns to Scale (VRS), with an output based efficiency measure (orientation), yields the results given in Table 2 (efficiency scores and weights) and Table 3 (peers).

Table 2: Efficiency scores and weights (VRS, output oriented)

Firms (SC)	Efficiency	Cost of Sales (weight)	TBL E2S Cluster (weight)	TBL E Cluster (weight)	Net Sales (weight)
Inditex	1	1.13493E-10	0	0.00019111	0
Esprit	1.134892999	1.03876E-09	0	0	4.34998E-10
GAP	1.235244068	0	0.001160358	0.021092224	0
H&M	1	0	0	0.018181818	0
MANGO	1	0	0.014084507	0	0
Uniqlo	1.105429723	0	0.001065516	0.019368249	0
Nike	1.020293636	0	0	0	0
PUMA	1	0	0	0.019607843	0
Target	1	0	0	0	0
M&S	1.064937474	0	0.001001959	0.018212959	0

Table 3: Peers and lambdas (VRS, output oriented)

Firms (SC)	Peer1	Peer2	Peer3	Inditex (λ_1)	MANGO (λ_2)	PUMA (λ_3)	Target (λ_4)
Inditex	Inditex	-	-	1	0	0	0
Esprit	Inditex	MANGO	-	0.015179	0.984821	0	0
GAP	Inditex	PUMA	-	0.924738	0	0.075262	0
H&M	Inditex	MANGO	-	0.934689	0.065311	0	0
MANGO	MANGO	-	-	0	1	0	0
Uniqlo	Inditex	MANGO	PUMA	0.669353	0.291866	0.038781	0
Nike	Inditex	Target	-	0.839679	0	0	0.160321
PUMA	PUMA	-	-	0	0	1	0
Target	Target	-	-	0	0	0	1
M&S	Inditex	PUMA	-	0.906753	0	0.093247	0

The results presented by Table 3 reveals that under VRS (output-oriented), which is the most generally assumption related to scale, after running the DEA, five firms and their supply chains were qualified as efficient (Inditex, H&M, MANGO, PUMA and Target). The zero weights (dual form) presented by the inefficient DMUs suggests the presence of slacks, which can be highlighted the ones related to the TBL clusters (Esprit and Nike). Some efficiency scores multiplied by TBL cluster (E2S,E) scores barely increments in sustainability reporting and consequently not representing to big a effort for a firm (e.g. Nike, from (51,37) to (52,38)). From a managerial perspective and for the sake of sowing the seeds of sustainability (including threshold and context related issues), it is more practical to reach for the TBL clusters scores of peers used more than once for comparisons (envelopment map), which in this technology are Inditex (90,54), MANGO (71,37) and PUMA (85,51).

Performing a Data Envelopment Analysis (DEA), under the technology assumption of Constant Returns to Scale (CRS), with an output based efficiency measure (orientation), yields the results given in Table 4 (efficiency scores and weights) and Table 5 (peers).

Table 4: Efficiency scores and weights (CRS, output oriented)

Firms (SC)	Efficiency	Cost of Sales (weight)	TBL E2S Cluster (weight)	TBL E Cluster (weight)	Net Sales (weight)
Inditex	1	1.13493E-10	0	0	0
Esprit	1.135673823	9.86456E-10	0.000844107	0	4.12232E-10
GAP	1.450511206	1.75034E-10	0	0.000294739	0
H&M	1.017915969	1.22594E-10	0	0.000206435	0
MANGO	1	9.67859E-10	0.014084507	0	0
Uniqlo	1.168538136	1.86341E-10	0	0.000313779	0
Nike	1.281638869	0	0	0	0
PUMA	1.232131792	6.67027E-10	0	0.001123202	2.78301E-10
Target	1.671264858	0	0	0	0
M&S	1.458435606	1.78691E-10	0	0.000300897	0

Table 5: Peers and lambdas (CRS, output oriented)

Firms (SC)	Peer1	Peer2	Inditex (λ_1)	MANGO (λ_2)
Inditex	Inditex	-	1	0
Esprit	Inditex	MANGO	0.031382	0.846638
GAP	Inditex	MANGO	0.916663	0.203425
H&M	Inditex	-	0.942348	0
MANGO	MANGO	-	0	1
Uniqlo	Inditex	MANGO	0.671825	0.340121
Nike	Inditex	-	1.705597	0
PUMA	Inditex	MANGO	0.031794	1.516689
Target	Inditex	-	5.401147	0
M&S	Inditex	MANGO	0.868534	0.49264

The results displayed in Table 4 reveals that under CRS, a less generally assumption related to scale, after running the DEA, in contrast with five efficient DMUs in VRS, just two firms and their supply chains were qualified as efficient (Inditex and MANGO). With eight DMUs classified as inefficient (and zero weights spotted), from a triple bottom line approach as whole, these firms and supply chains will be better off if they consider Inditex as their benchmarking and role model, in terms of enhancing sustainability practices and reporting. MANGO is also a peer to be considered, despite the TBL E related caveat.

The Table 6 provides the outlook on scale efficiency (SE) of the firm´s supply chains and in which part of the production function they fall.

Table 6: Scale Efficiency and Frontier Position (IRS, MPSS, DRS)

Inditex	Esprit	GAP	H&M	MANGO	Uniqlo	Nike	PUMA	Target	M&S
1	0.981	0.999	0.982	1	0.992	0.805	0.812	0.598	0.981
MPSS	IRS	IRS	DRS	MPSS	DRS	DRS	DRS	DRS	DRS

From the Table 6, the managers are called to action stemming from a double source. Firstly, from the efficiency scores compelling them to, on the one hand, the reporting practices their companies are considering for defining content, materiality, and context, while rethinking social, economic and environmental practices for more sustainable supply chains, on the other hand. Secondly, the economies of scale regarding in which part of the technology frontier their firms are falling. Esprit and GAP are on the IRS part of the frontier, whilst Uniqlo, Nike, PUMA, Target, and M&S are on the DRS part of the frontier. Both are the flipsides of the same coin, in terms of calling for some kind of high level approach to tackle the issue, leading to an invaluable occasion to analyzing impacts, risks and opportunities regarding sustainability and its inexorably increasing role in the future of any entrepreneurship.

5. Discussion

In the literature, there is a lack or a trend to overlook the importance that DMA takes on the G4 CSR reporting. It is possible to shed light over this subject using a Disclosure as an example. The G4-EN33 (Significant actual and potential negative

environmental impacts in the supply chain and actions taken) ratio between the Indicators and the DMAs gives a vital importance to addressing the management approach. The guidance for DMA outlines the need to describe how a firm identifies and prioritizes suppliers for assessment, actions taken, how expectations are established and defined in contracts with suppliers, to name a few. Clearly, there is an evident interdependence between Indicators (quantitative, in this case) and DMAs (qualitative, in this case).

In essence, the measures are not just serving as a "thermometer" of sustainable practices. Instead, they are in charge of inducing leadership, instigating benchmarking, making firms want to take the edge (frontier vs. average methods) on TBL solutions and at the same time instilling innovation. Each Disclosure has an importance of its own and must make room for capturing the "**effects**" on TBL implementation/operation, revealing some kind of TBL trend or lack of it.

Notwithstanding, the CSR as the synergy of Disclosures (Indicators + DMA) is becoming a feasible and reasonable proxy for measuring sustainability performance and efficiency on supply chains. Although indirectly, the model can be classified as useful tool for analysis (rear mirror). The results rendered by DEA processing can confirm that companies (and supply chains) considered efficient (or almost) are committed to sustainability, according to their CSR reports, like Inditex, MANGO, PUMA and H&M. Nevertheless, it can´t be seen as a "carte blanche" for ignoring the challenges of high resource demands, difficult multiple labor issues and heavy waste (production and disposing). Remy & Swartz (2016) claims that Zara (Inditex) offers 24 new clothing collections yearly, while H&M offers a range of 12 to 16 refreshed on a weekly basis. This reinforces the context requisite on sustainability reports and at the same time requires the development of feasible and meaningful thresholds based on best practices.

6. Conclusion

Carrots and Sticks 2016 Edition report identifies the surge in sustainability reporting instruments in place: almost 400 instruments in 64 countries. This suggests increased commitments and efforts to achieve transparency/accountability. Although, the large number and variety of instruments also pose challenges for reporting organizations (Bartels, Fogerlberg, Hoballah, & Van der Lugt, 2016). Consequently, between no reporting and deciding which framework to use for this task, it is better to choose a meaningful one and stick to it.

The analysis conducted herein made use of performance indicators set by GRI G4 Guidelines. Therefore, standard metrics was not a problem. Three issues can be interpreted as the mainstream difficulties in performance indicators. First, whether the indicator is present or not in the report. Second, the metrics required by the Indicator were presented to the full or halfway (leading to the three layers for Disclosures). Last, different standards, methodologies and assumptions used by reporters to obtain quantitative data to fulfill Disclosure requirements. The workaround to equalize uneven data and blend quantitative and qualitative data together was the idea of the TBL Clusters, Socio-Economic and Environmental, clearly including the social dimension into the analysis.

An important feature of the scale for computing scores for TBL clusters, is allowing mixing qualitative and quantitative data. In consequence, it enabled the combination of financial and non-financial (sustainability) for application in a DEA structure. When it comes to sustainability, the lack of a consistent threshold and context is an ongoing problem. Therefore, DEA with its piecewise comparison and data-driven non-parametric technique overcomes this limitation, at the same time providing meaningful readings of the practices in the real world. This approach has the limitations of not applying the actual data reported, instead using a score as a proxy. However, it was possible to account for any Disclosure, including the ones which clearly permit identify the laggards in sustainability measurement and reporting (e.g. failing to do any reporting on G4-EN17 – Other indirect greenhouse gas (GHG) emissions (Scope 3), a typical supply chain Disclosure).

One of the main topics that gives consistency to the present work is also an issue for future research to overcome – the restriction to CSR report analysis to GRI G4 reports. The desired state is developing a methodology for sustainability performance measurement independently of the framework adopted to structure the disclosing of firms (including their supply chains) TBL practices. Thus, there is a need for devising a methodology (measures and how to apply) whose main strength is being "frameworkless" providing researchers and practitioners a useful tool or "sustainability compass".

The model was processed as aggregated data (bundle). In order to take this research further, there is a need to some sort of disaggregating data from the TBL Clusters. Therefore, it might allow to understand the Disclosure contribution or trend to whether a supply chain can be considered efficient or not. Along with unbundling data, other questions stand. What kind of signals a GRI Indicator/DMA give? What about sustainability trends? These questions provide more avenues for future discussion and researches on SSCM.

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