

Measuring the Sustainability of Global Supply Chains: Current Practices and Future Directions

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ABSTRACT

Researchers and practitioners alike have become increasingly interested in the environmental performance of global supply chains. Does improving the environmental performance of a single link of a supply chain improve the entire chain's sustainability — that is, economic, social, and environmental outcomes? Answering this question is impossible without a way to measure performance, and this paper seeks to answer the question: What are the goals, requirements, and challenges of an overall measure of supply chain sustainability? In the process of answering this question, three things are accomplished. First, more than 70 articles and books are reviewed to give an overview of current methods used to improve business sustainability and measure performance. Second, a new framework of supply chain sustainability is introduced. Third, three research propositions related to global supply chain sustainability measurement are presented. This research has implications for scholars who can use the framework and propositions to direct new theoretical and empirical analyses. The research also has implications for practitioners — managers, policy makers, and community stakeholders with an interest in making global supply chains more sustainable.

INTRODUCTION

In recent years, many firms have begun efforts to 'green' their businesses. The impetus for these efforts comes from external forces, such as increased regulation and changes in consumer preferences, and from internal forces, such as the values of the firms' leadership. For example, manufacturers of large appliances must take new regulations regarding product recovery into consideration as they design the next generation of washers and dryers. Drivers in the United States (U.S.), once lovers of large SUVs, now pay top-dollar for smaller and more environmentally-friendly hybrid vehicles. Manufacturers have re-examined waste from their processes to reduce emissions, save energy, and find alternative uses for byproducts.

Many firms, governments, and citizens now recognize the need to go beyond green and have begun thinking in terms of *sustainability*. In general terms, sustainability is defined as economic practices which 'meet the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). Building on the definition of sustainable operations management by Kleindorfer et al. (2005), we define a *sustainable supply chain* as one that is operated in a way that generates 'competitive returns on its capital assets without sacrificing the legitimate needs of internal and external stakeholders and with due regard for the impact of its operations on people and the environment' (p. 489).

Previous research related to supply chain sustainability can be divided into two broad areas. The first area has to do with 'local' efforts to improve sustainability. This topic covers the tools and techniques that firms use to improve environmental performance as well the efforts they make to report

results to outside stakeholders. This research raises an important question: Does improving one dimension of sustainability for one link in a supply chain actually increase the overall sustainability of the entire chain? The second broad area of research has to do with 'global' performance measurement; that is, how one assesses the performance of industries, economies, and countries. This area covers the development of various composite indicators: multi-dimensional measures designed to evaluate complex concepts such as human well-being, industrial competitiveness, and the performance of health care systems. While many important lessons can be gleaned from this work, it does not yield practical performance measures that managers can use to improve supply chain sustainability.

The goal of this paper is lay a theoretical foundation for the development of an objective measure of global supply chain sustainability. In the course pursuing this goal, the paper makes three contributions. First, it provides a review of the tools and methods currently used by businesses to incorporate sustainability into their business practices. Second, it introduces a new framework for thinking about and exploring supply chain sustainability. And third, it presents three research propositions related to global supply chain sustainability measurement, which can serve as a springboard for future theoretical and empirical investigations.

REVIEW OF SUSTAINABILITY TOOLS

As mentioned above, firms are becoming more interested in sustainability for many reasons, some internal and some external. The first line of attack is to address 'local' issues; that is, to work on things that are within their immediate control. Four ways that firms do this are discussed below.

Decision-Making Tools

Once a firm has decided to take action with regard to sustainability, where does it begin? Many tools and methods have been developed in the last 20 to 30 years to help incorporate sustainability concepts into business decision making. One of the most prevalent, *Life Cycle Assessment* (LCA), is a tool used to evaluate the environmental impact of a product by identifying and measuring all of the materials and energy required to design, produce, deliver, and consume a product. Although LCA is an important and powerful tool, it may difficult to obtain the relevant data and that it ultimately involves subjective evaluations by those performing the analysis (U.S. E.P.A., 2006). In addition, its sole focus is environmental factors.

Robèrt et al. (2002) discuss many sustainability tools and frameworks, including ISO14000, LCA, Ecological Footprinting, Factor 4, Factor 10, Sustainable Technology Development, Natural Capitalism, and The Natural Step Framework. The authors discuss how the different tools can be used and how they complement each other. Waage et al. (2005) build on the previous discussion by exploring the types of questions that practitioners face when incorporating sustainability factors into business decision making. For example, which tool(s) should be used in a particular context?

Rather than focus on the environmental impacts themselves, other research focuses on instruments to evaluate costs and benefits of green practices. Seuring (2001) proposes a framework for evaluating the costs for the entire supply chain, using the fashion industry as a backdrop. De Groene and de Haan (2001) discuss the development and application of a method to measure environmental costs and benefits for small- and medium-sized firms. Barbiroli (1996) observes that traditional productivity measures fail to capture the complex economic and technical efficiency of production processes and proposes a new measure, which is the sum of 12 economic, environmental, quality, and productivity performance indices.

Extending these ideas, Barbiroli and Raggi (2003) develop a methodology to evaluate the economic impact of environmental innovations for a particular process and develop a numeric index called the *global efficiency ratio*. Sarkis (1999) develops a two-step methodology to evaluate environmentally conscious manufacturing (ECM) programs. Relevant factors are sorted using the Analytic Network Process (ANP), and then the ECM program alternatives are evaluated using Data Envelopment Analysis (DEA).

Epstein and Roy (2001, 2003), Epstein and Wisner (2001), and Figge et al. (2002) discuss how a *balanced scorecard* approach can be used to track several key environmental, social, and economic measures of performance, which enables managers to look beyond a single measure of performance. Presley et al. (2007) develop an analytical framework with which firms can integrate sustainability factors into long-term, strategic decisions. All of the tools discussed above can play an important role in improving the environmental and sustainability performance of firms. Nevertheless, measuring these improvements can be elusive.

Environmental and Sustainability Reporting

Another way that firms attempt to improve sustainability and signal concern with issues beyond the financial bottom line is by creating reports about their sustainability performance. These reports often deal exclusively with environmental performance and are often separate from the usual annual reports. One important form of sustainability reporting is *Triple Bottom Line* (TBL) accounting, which refers to the expansion of traditional accounting of financial performance to include environmental and social performance. TBL accounting is driven by the idea that businesses must also answer to 'stakeholders,' i.e., all of those influenced by the actions of the firm. While TBL accounting is becoming more widely used, few standards exist, and the benefits to firms of engaging in this type of reporting are not always clear.

Fatkin (2001) provides an overview of corporate environmental reporting, which was pioneered by Polaroid, and concludes broader measures of performance and better standards are needed. The *Global Reporting Initiative* (GRI) is a non-profit, collaborative effort to develop standards of sustainability reporting. The latest reporting guidelines, issued in October 2006, detail how firms can communicate their environmental, social, and economic performance to the public (GRI, 2006). Hussey et al. (2001) discuss how the GRI guidelines can be operationalized, and Veleva et al. (2003) report on the types of indicators firms currently use to describe their sustainability efforts, concluding that supply-chain level measures are needed. Similar in spirit to GRI, the *Global Environmental Management Initiative* (GEMI) is a group of firms that work together to 'foster environmental health and safety (EHS) excellence' (GEMI, 2009). However, rather than promote generic reporting guidelines, GEMI shares information about tools and practices and attempts to provide leadership in EHS management and sustainable development.

A recent study indicates that sustainability reporting rates have increased dramatically in the last few years. Indeed, in the U.S. — which lags behind many other countries — reporting has doubled since 2005, and 74 percent of the top 100 firms reported some sort of corporate responsibility information in 2008 (KPMG, 2008). While this is encouraging on the surface, previous research has suggested that many firms engage in sustainability and environmental reporting for symbolic reasons rather than out of a genuine concern for accountability to a wider set of stakeholders (Adams, 2004); thus, an increase in reporting is not always a reflection of increased sustainability (Price, 2008). Firms can choose to report

whatever information they want, so there is obviously an incentive to focus on positive outcomes. These findings suggests that more objective measures of sustainability performance would be useful.

Green Sourcing

Another important way that firms have attempted to increase the sustainability of their businesses is by incorporating environmental issues into their purchasing policies. For example, firms can work with suppliers to find raw materials with reduced environmental impact. Researchers have studied the strategic aspects of green sourcing (Sroufe, 2006; Kam et al., 2006) as well as the more practical aspects (Handfield et al., 2005; Holt, 2004; Min and Galle, 1997, 2001). Green et al. (1998) and Schlegelmilch et al. (1996) examine the relationship between green purchasing and environmental performance, while Carter et al. (2000) and Klassen and McLaughlin (1996) study how green purchasing practices affect a firm's financial performance.

Nagel (2006) proposes a measure of environmental performance that original equipment manufacturers can use to evaluate their suppliers using a set of equations that describes the relationship between the inputs and outputs of a production process. Handfield et al. (2002) illustrate the use of a quantitative technique with which to evaluate suppliers based on a number of dimensions, including waste management, certifications (e.g., ISO14000), and compliance with government regulations. Walton et al. (1998) use a case-based approach to identify key focus areas for improving the purchasing function's impact on environmental performance. This research on supplier evaluation also focuses primarily on the environmental dimension and does so only for a single link in the supply chain.

Supplier Codes of Conduct

Another important area of research examines supplier codes of conduct (SCC). As the name suggests, such codes, which may be voluntary or required, delineate desirable and undesirable behaviors for suppliers. SCC are one of the key mechanisms by which large corporations attempt to ensure ethical behavior on the part of their suppliers (Roberts, 2003; Locke and Romis, 2007). SCC typically focus on labour issues and are one of the main ways in which the social dimension of of supply chain sustainability has been addressed.

Much research on SCC addresses questions about the meaning of corporate social responsibility (CSR) and ethical behaviour and explore how SCC play a role in these areas (Roberts, 2003; Logsdon and Wood, 2005; Sobczak, 2006). Other research examines the structure and effectiveness of SCC, using different methodologies (Egels-Zandén, 2007; Sethi, 2003; Jiang, 2009a and 2009b; Doig and Wilson, 1998; Kaptein and Schwartz, 2008). Many other researchers have conducted case studies of SCC within particular industries, such as apparel (Emmelhainz and Adams, 1999) and footwear (Lim and Phillips, 2008); individual companies, such as IKEA (Pedersen and Andersen, 2006) and Reebok (Yu, 2008); and regions, such as the United Kingdom (Schlegelmilch and Houston, 1989), South Korea (Frenkel and Kim, 2004), Brazil (French and Wokutch, 2005), and Ireland (O'Dwyer and Madden, 2006).

In summary, there has been a great deal of work on the environmental dimension, and, to a lesser degree, the social dimension of sustainability of businesses. However, most of this research has focused on single processes or firms and focused on one dimension at a time. Works examining the larger supply chain context are primarily descriptive. While these are important steps toward understanding sustainability, there is still a need to look beyond a single link in the supply chain and to look at measures which integrate multiple dimensions of performance.

REVIEW OF PERFORMANCE EVALUATION METHODS

Many researchers have attempted to measure industry-, economy-, and country-level performance with respect to different dimensions, and our understanding of global supply chain sustainability measurement can benefit from an examination of these methods.

Closed-Loop Supply Chains

The term *supply chain* refers to the system of people, activities, information, and other resources designed to transform raw materials into finished goods and services and deliver them to the end consumer. An important change in supply chain management in the last 20 years has been to expand the definition from an open-loop to a closed-loop supply chain, i.e., to include the reverse flows of material and waste. Figure 1 illustrates the forward and reverse flows for a typical supply chain, where each node in the diagram represents a sub-network of organizations and businesses such as suppliers.

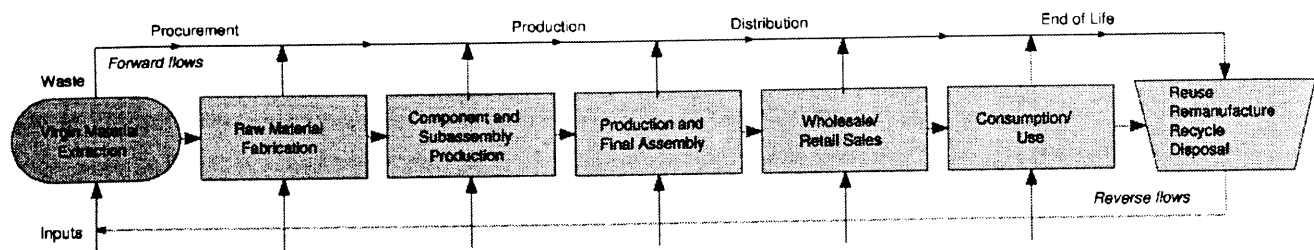


Figure 1: Typical Forward and Reverse Flows in a Supply Chain

Much of the research on closed-loop supply chains has focused on the reverse logistics and processes needed to recover, remanufacture, and/or recycle products. Dekker et al. (2004) present numerous quantitative models related to closed-loop supply chains, including models addressing network design, production planning, and inventory control. Flapper et al. (2005), in contrast, describe a number of case studies, discussing closed-loop supply chain applications in many firms and industries. Gungor and Gupta (1999) review the extensive literature that has evolved regarding issues of product recovery, while Thierry et al. (1995) focus on strategic, conceptual issues related to the subject.

While product recovery and reverse logistics are important topics, they represent a small part of the broader concept of *green supply chains*. Sarkis (2003) discusses many strategic issues related to the development of green supply chains, and the edited volumes of Sarkis (2001, 2006) cover virtually every aspect of green supply chains, including many case studies. Khoo et al. (2001) present a detailed case study and discuss the use of various modeling tools to assist in the development of a green supply chain. Svensson (2007) argues that the traditional view of a supply chain is too myopic and that to be sustainable, the definition of a supply chain must be expanded. The author proposes that supply chains be classified according to the degree of renewable and recycled resources used. See Srivastava (2007) for an extensive review of green supply chain research.

Supply Chain Performance Measurement

Gunasekaran et al. (2001) introduce a framework for measuring supply chain performance in different areas and propose metrics for different dimensions and areas of the supply chain. Gunasekaran et al. (2004) survey the practices and attitudes of U.K. firms and conclude that there is plenty of interest in measuring performance but some uncertainty as to how to go about it. Both of these papers highlight the

challenges of measuring supply chain performance, and this point is further echoed by Hervani et al. (2005).

An important tool for evaluating supply chain performance is the Supply Chain Operations Reference model (SCOR): a framework for describing, measuring, and comparing supply chains (Supply-Chain Council, 2008). The latest version of SCOR also includes metrics aimed at improving sustainability such as emissions cost per unit and waste produced as a percentage of product produced (Blanchard, 2008). Most efforts towards evaluating supply chain sustainability have focused on environmental issues (e.g., McIntyre et al., 1998). Other research has sought to extend LCA and similar methods to supply chains (Lambert, 2001; Faruk et al., 2001). Cholette and Venkat (2009) study the energy usage and carbon dioxide emissions in supply chains, with particular emphasis on the distribution of wine.

Kumar et al. (2001) develop a methodology to assess the environmental impact of a product and the processes required to produce it. A measure is developed that captures the social, ecological, and economic impacts of a product with respect to dimensions such as manufacturing, packaging, use, and disposal. Tyteca (1996) develops a 'production efficiency' method to measure firm-level environmental performance. Färe et al. (2004) expands and modifies the method of Tyteca (1996) to allow country-level environmental performance measurement. Kainuma and Tawara (2006) develop a model to examine the trade-offs between different dimensions of performance for an entire supply chain.

Composite Performance Indicators

Economists, sociologists, ecologists, policy makers, and others have long sought to measure the performance of a country along one or more dimensions. Just as the gross domestic product (GDP) is accepted as a measure of a country's economic fortitude, indices have been developed to measure a country's performance in many other dimensions such as healthcare (Jacobs et al., 2004, 2006) and citizen well-being (Balioune-Lutz, 2006). Freudenberg (2003) offers a general critique of composite indicators, and Nardo et al. (2005) present a 'how-to' guide.

There has also been much work specifically on *sustainable development*, proposing frameworks (Corbièr-Nicolliere et al., 2003; Labuschagne et al., 2005b), exploring philosophies (Levett, 1998), discussing technical challenges (Munasinghe, 1993), and developing specific methods (Bossel, 1999; Cherchye and Kuosmanen, 2006; Custance and Hillier, 1998; Giampietro et al., 2001; Graedel and Allenby, 2002; Pintér et al., 2005).

One important composite metric is the *Environmental Sustainability Index* (ESI). Developed by a consortium of academic and government institutions, the purpose of the ESI is to benchmark the ability of nations to protect the environment over the next several decades (Yale, 2005). The index is based on 76 variables, which capture information related to the resources, policies, and performance of nearly 150 nations around the world. The 76 variables are reduced to 21 indicators, and a country's ESI score is computed using these indicators. Five main factors underlying the 21 indicators, such as 'environmental systems' and 'social capacity', are identified. In the next section, we discuss some ways that the lessons of the ESI can be translated to the context of a supply chain.

MEASURING GLOBAL SUPPLY CHAIN SUSTAINABILITY

In this section, we discuss the development of a quantitative measure of supply chain sustainability. The objective of this research is to lay the groundwork for a measure that captures the heart of this inherently complex and multi-dimensional concept.

Building Blocks

A measure that incorporates factors from more than one dimension, rather than a single dimension, gives a more complete picture of sustainability. However, it also raises a number of challenges with respect to measurement. Freudenberg (2003) identifies five steps involved in the development of composite indicators: (1) Develop a theoretical framework, (2) Identify and develop relevant variables, (3) Standardize variables, (4) Weight and group variables, and (5) Perform sensitivity analysis. Each of these areas has challenges associated with it. The primary challenge is developing a theoretical framework. Many sustainability frameworks have been proposed, primarily in the context of country-level performance. Using some of these frameworks as a foundation, Labuschagne et al. (2005b) propose a framework to assess industry sustainability. We, in turn, adapt their framework to the context of a global supply chain. The framework provides a lens through which one views sustainability and thus will have a major effect on which variables to include and/or construct. Figure 2 illustrates the basic framework that will be used to guide the development a measure of supply chain sustainability.

Using the recent work of Carter and Rogers (2008) as a guide, we use a conceptual theory building method to develop research propositions based on the above framework. These propositions — one for each dimension of sustainability — seek to ‘explain an event, provide understanding, or suggest testable hypotheses’ (Meredith, 1993, p. 8). Such an approach is not without challenges (Weick, 1989; Meredith, 1993; Wacker, 1998); however, what Carter and Rogers (2008) did for supply chain sustainability, we hope to replicate here with respect to the *measurement* of global supply chain sustainability performance. While a specific measure is not proposed, the variables and indicators discussed below represent a synthesis and integration of concepts explored in earlier studies on sustainability and global supply chain management.

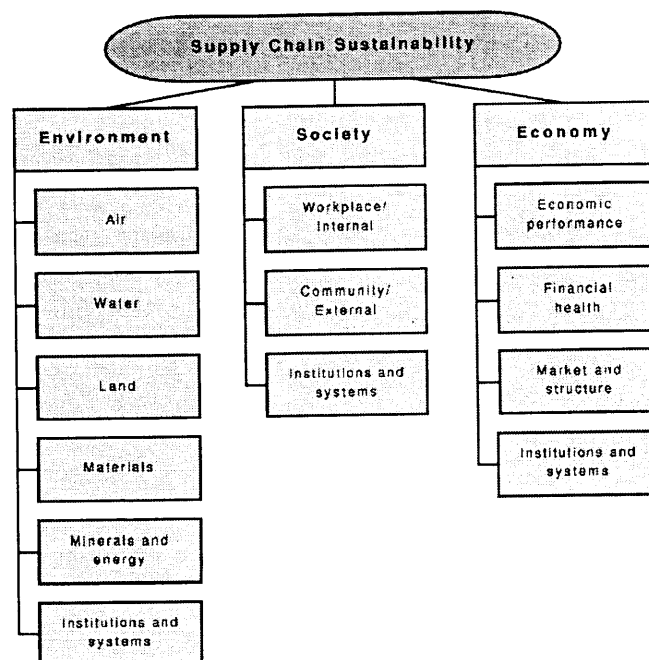


Figure 2: Supply Chain Sustainability Framework

Sustainability Measures and Indicators

Sustainability involves factors in three broad dimensions: environment, society, and economy. Below we identify some variables that relate to each dimension.

Environmental Factors

The term *environment* typically refers to the natural environment: all of the living and non-living things that occur naturally on Earth, including the land, water, plants, animals, etc. Improving environmental sustainability means reducing the ecological footprint of the supply chain. Of the three dimensions, the environmental aspect of supply chain management has been studied the most. Handfield et al. (2002) identify more than 50 environmental performance indicators by which suppliers can be evaluated; Labuschagne et al. (2005a) also identify many factors related to environmental sustainability. We divide the environmental factors into six categories. (1) *Air*: Refers to the local impacts, such as carbon monoxide emissions, as well as global impacts, such as ozone depletion. (2) *Water*: Refers to both quality and quantity impacts, e.g., toxic discharges as well as total usage. (3) *Land*: Refers to how much land is used, how it is used, and the impacts of the use, such as soil pollution. (4) *Materials*: Refers to quantity of material used, the type of material used, and the potential effects of that material. (5) *Minerals and energy*: Refers to the use of non-renewable mineral and energy resources. (6) *Institutions/Systems*: Refers to the values, procedures, and systems — both internal and external — that relate to the environment. Table 1 provides example measures within each category.

Table 1: Example Environmental Metrics and Indicators

Category	Examples
Air	Emissions (per unit produced) Use of ozone depleting substances
Water	Water used (liters) Water reuse/recycling
Land	Soil pollutants released Landfill waste (tons)
Materials	Post consumer recyclable content (%) Hazardous material content Mass of materials used Global warming potential of materials (e.g., CFCs)
Mineral and energy resources	Energy from renewable sources (%) Total energy used
Institutions/Systems	ISO 14000 certification 'Energy Star' product labeling Public reporting of environmental performance Regulatory compliance (e.g., EPA) Environmental Management System (EMS) in use

These indicators, along with the aforementioned research on improving supplier sustainability, lead to the following proposition:

Proposition 1: Supply chains that explicitly measure environmental performance will perform better in all dimensions of sustainability.

Anecdotal evidence of the validity of this proposition can be found in the literature related to 'greening' suppliers (e.g., Walton et al., 1998).

Social Factors

The social dimension of sustainability relates to the human capital of the supply chain. Improving sustainability with respect to the social dimension involves developing and maintaining business practices that are fair and favorable to the labor, communities, and regions touched by the supply chain. Social

performance indicators are grouped into three categories. (1) *Workplace*: Refers to the internal human resources, i.e., those who work within the supply chain. (2) *Community*: Refers to all people outside of the supply chain, including those who are directly and indirectly affected by the chain's performance. (3) *Institutions/Systems*: Refers to the internal and external systems, procedures, and values that relate to the social dimension. Appropriate measures and indicators within each category will depend on the industry, location, cultural norms, and so on. Some items, such as healthcare, span categories, since they have both internal and external implications. Example measures and indicators are listed in Table 2. This discussion leads to the following proposition:

Proposition 2: Supply chains that explicitly measure social performance will perform better in all dimensions of sustainability.

Literature on SCC effectiveness (e.g., Egels-Zandén, 2007) provides some evidence related to this proposition.

Table 2: Example Social Metrics and Indicators

Category	Examples
Workplace/Internal	Wages Employee contracts Healthcare benefits Opportunities for career development Number of accidents and/or deaths per person-hour of work
Community/External	Product liability (e.g., recalls) Healthcare benefits
Institutions/Systems	Supplier evaluation includes social factors Hours of safety training per employee Regulatory compliance (e.g., OSHA) Health and Safety Management System in use

Economic Factors

The economic dimension of the supply chain refers to the profits earned by the members of the chain as well as the economic benefits realized by the host nations, regions, and communities of those members. Thus, this dimension goes beyond the internal profit earned by a particular company, and some factors that fall under this category may not be easily measured in financial terms. Economic factors are sorted into four categories. (1) *Economic performance*: Refers to the ability of the firm to carry out its operations as well as the market value of the firm. (2) *Financial health*: Refers to well-being and long-term viability of the firm with respect to financial resources. (3) *Market and structure*: Refers to health of the market and the configuration of the supply chain. (4) *Institutions/Systems*: Refers to the internal and external systems, procedures, and values that relate to the economic dimension. Example measures and indicators are listed in Table 3. This discussion leads to the following proposition:

Proposition 3: Supply chains that explicitly measure economic performance do *not necessarily* perform better with respect to the environmental and social dimensions of sustainability.

This proposition is somewhat contradictory in light of the first two propositions. Why does measuring environmental performance, for example, improve economic performance but not vice versa? We conjecture that this result relates to the hierarchical nature of the measures. Put differently, firms already measure economic performance, but they do not (generally) measure environmental performance. The increased scrutiny that accompanies expanded measurements will reveal waste and other opportunities for improvement, thus enabling the firm to benefit economically.

Table 3: Example Economic Metrics and Indicators

Category	Examples
Economic performance	Order fill lead time Product defect rate Transportation cost per unit Productivity Market value
Financial health	Profitability ratio Cost of goods sold Return on working capital
Market and structure	Degree of vertical integration Depth of supplier pool Breadth of customer base Market share
Institutions/Systems	Regulatory compliance (e.g., CPSC) ISO 9000 certification Quality Management System in use

Clearly, the example metrics in the tables do not represent exhaustive lists, and some of the items overlap — both within and between dimensions. The primary impediment to evaluating such complex, multi-dimensional concepts as sustainability is not lack of inputs; rather, it is what to do with the many inputs available. As some experts have noted, ‘It is not difficult to come up with ideas for indicators...the problem is selecting the most appropriate from the myriad possibilities’ (Custance and Hillier, 1998). Measurement challenges are discussed in the next section.

Assessment Challenges

In addition to the conceptual challenge of what factors to include, many other technical and practical challenges exist. Assuming that all of the relevant factors have been identified, how does one winnow, reduce, combine, etc. the factors to distill a single number? The reduction process will no doubt involve some subjective aspects, e.g., how does one weigh the environmental factors compared with social and economic factors? A variety of techniques have been used to address these issues, such as factor analysis and principal components analysis (Härdle and Simar, 2007), Data Envelopment Analysis (DEA) (Reiner and Hofmann, 2006), the Analytic Network Process (ANP), and the Analytic Hierarchy Process (AHP) (Handfield et al., 2002; Yakovleva et al., 2008).

Data collection is another major challenge in the process of evaluating sustainability. Although we may believe that a particular factor is relevant, there is no guarantee that a given company monitors this factor. For example, Nagel (2006) found that a large proportion of firms studied did not (or could not) accurately measure the mass of materials flowing through their production processes. Another important measurement issue is how to standardize the variables. This issue is discussed extensively in the ESI report reviewed in the last section (Yale, 2005).

Despite these challenges, simply expanding one’s thinking about sustainability and supply chain performance can be useful. A truly comprehensive measure of supply chain sustainability is perhaps impossible. It is important to note, however, that the ultimate goal of this type of metric is not to have a perfect measure; rather, the goal is to expand our thinking about what sustainability means and to enable more rigorous evaluations of different supply chain configurations.

SUMMARY AND CONCLUSIONS

Most parties agree that improving supply chain sustainability is a desirable goal. However, measures of sustainability have not been forthcoming. Furthermore, most management-oriented research related to sustainability has focused only on improving environmental performance. While this is a worthy objective, the environment is only one dimension of sustainability. The main purpose of this paper has been to establish the need for and to begin the development of quantitative measures that (1) incorporate factors from all dimensions of sustainability and (2) capture the performance of the entire supply chain, rather than individual firms. These measures can then be used to explore different supply chain configurations and practices.

Two broad areas of relevant research were discussed. First, the techniques used by firms to improve local performance were examined. These tools typically focus on environmental performance for one, or perhaps two, links in the supply chain. The second broad area of research discussed deals with performance measurement at higher levels. Significant work has been done on supply chain performance measurement, particularly with respect to 'greenness.' Composite performance indicators, such as the Environmental Sustainability Index, attempt to capture complex, sometimes 'fuzzy' concepts with single number. While these indicators serve an important purpose and set an encouraging example, they are difficult to apply in a supply chain context.

To address the need for measuring sustainability of a global supply chain, we first proposed a simple framework based on the traditional dimensions of sustainability: environment, society, and economy. Next, sub-dimensions for each area were identified and discussed. Example metrics and indicators were proposed for each of the sub-dimensions. The challenges associated with measuring the factors and constructing a composite measure were discussed. Finally, we introduced three propositions related to global supply chain sustainability measurement. These propositions lay the groundwork for future theoretical exploration in this area. In addition to developing simple analytical models to develop measures of sustainability, future research should also include in-depth studies of specific supply chains and/or industries.

Clearly, much work remains to be done to develop a measure of global supply chain sustainability. However, one of the main lessons of this paper is that the *process* of developing a measure is perhaps more important than the actual measure. First, it forces us — manufacturers, suppliers, governments, and consumers — to take a broader view of sustainability. Second, it highlights the need to consider the entire supply chain rather than just the individual parts of the chain. Current practice allows decision makers to focus myopically on factors and/or links that are the most appealing or convenient. An athletic shoe maker can focus on reducing hazardous materials, while ignoring the sweatshop conditions for the workers making the shoes. A large retailer can focus on savings in transportation costs, while ignoring the environmental impact caused by the consumption patterns facilitated by its 'throw-away' goods. Only by enabling — or perhaps forcing — managers to recognize a broader perspective can we begin to make progress toward true sustainability.

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