Is the dense supply chain network more environmentally friendly?

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Abstract
Moving beyond a single organizational view, with the help of a corporate database, we investigate the supply chain network of major manufacturers in the aviation sector to address the above question. Specifically, we apply network characteristics to empirically determine attributes that are salient for environmental sustainability within a supply chain network.

Keywords: Supply chain network, environmental sustainability, aviation sector

Introduction
Today, the sustainability focus has shifted from a sole emphasis on an organization's financial performance to include also its social and environmental performance. The prominence of issues such as global warming, and climate change in the public discourse has fostered an increased emphasis on improving the environmental performance of organizations. Recent estimates such as Melville (2012) peg the contributions of organizations to the total US greenhouse gas (GHG) emissions as between 39% and 47%. These estimates include the emissions incurred during transportation. Even when we ignore such assumptions, the industrial and commercial sectors already account for about 34% of the US GHG emissions (United States Department of State 2010). Thus, organizations are at the center of a nation's carbon footprint.

As supply chain emissions account for about 85% of an organization's total carbon footprint (Mathews et al. 2008), and transportation is the second largest contributor to CO_2 emissions in the US (EPA 2011), there is thus a need to focus on the organization's supply chain when examining organizational carbon footprint. This perspective is gaining currency in the context of green supply chain management (GSCM) (Hall 2001). Indeed, GSCM has witnessed both analytical as well as empirical research on the environmental impact of an organization's supply chain (Srivastava 2007). This paper adopts an empirical approach to investigating the environmental impact on a supply chain network through an organization's position in the supply chain.

Empirical research on the GSCM tends to define the boundary on the supply chain in different ways based on the research question. For instance, we have green purchasing (Zhu and Sarkis 2004). Such studies usually employ case studies and surveys (Srivastava 2007). The focus has been predominantly on specific practices such as remanufacturing, and recycling.

Of late, there has been a few attempts to investigate the financial impact of supply chain

emissions (Delmas and Nairn-Birch 2011). Here, the focus has been on the supply chain of an organization. Moving beyond the organization as the unit of analysis, research such as Ashraf et al. (2012) focus on the organization's network and its impact on environmental performance. However, the focus is on alliances under a specific mechanism.

There is a dearth of empirical studies that examine the supply chain network and the associated environmental performance, despite the fact that supply chains are crucial to an organization's carbon footprint. We attempt to fill this research gap by ***exploring*** the supply chain network, and the environmental performance of the large aircraft manufacturers. We construct the supply chain network for these manufacturers by investigating their suppliers and customers. In so doing, we embrace the complexities and interrelationships among the different organizations in a supply chain network. We further examine the environmental performance of the manufacturers with a focus on understanding whether supply chain network characteristics are salient to an organization's environmental performance.

Our paper is structured as follows. We review the relevant literature before proposing our framework. Next, we describe our dataset and analysis procedure. This is followed by the results, discussion, and concluding remarks.

Background and Theoretical Framework

The GSCM literature has applied a variety of theoretical lenses. For instance, research focused on specific practices have used institutional theory (Aerts et al. 2006), resource based view (RBV) (Sarkis et al. 2011), and stakeholder theory (de Brito et al. 2008). The research that extends beyond specific organizations or dyadic relationships such as the relationships between organizations and their suppliers has used social network theory (SNT) to explore the supply chain networks. SNT posits that organizational outcomes are consequences of the relationships between organizations (Jones et al. 1997). Seyfang (2006) reasoned that SNT can explain the performance outcome of the buyer - supplier relationship. Organizations with far more suppliers and customers are more susceptible to the adoption of GSCM practices and have less control over the adoption decision (Maignan and McAlister 2003). However, whether an organization that possesses a dense supply chain network is indeed better on environmental performance needs further investigation.

Supply Chain Network (SCN) and Environmental Performance

The idea of a network as being a key to an organization's adoption of sustainability practices was first captured by Rowley (1997), who argued that organizations with a large number of ties in the network (as in dense network) are unable to withstand pressures (normative and coercive) from the stakeholders. Drawing from Rowley's perspective on the influence of network density on a organization's ability to respond to stakeholder pressure, Maignan and McAlister (2003) proposed that organizations with more number of suppliers and customers (possess a dense network) will proactively adopt sustainability practices. However, if an organization is the central actor in a network, it can manipulate the information-flow in the network, and thus can withstand stakeholder pressure and can refrain from proactively adopting sustainable practices.

Extending the network perspective to environmental performance, we argue that organizations operating within a dense supply chain network will be more environmentally friendly due to the increased pressure from stakeholders. Further, greater consumer awareness of an organization's carbon footprint among consumers will lead to greater consumer pressure on the focal organization to reduce its carbon footprint. Likewise, suppliers are forced to reduce their carbon

footprint due to the various institutional factors. They will therefore exert pressure on the focal organization to become more environmentally friendly to improve their reputation due to their association with the organization with a lower carbon footprint. We propose that focal organizations in a dense supply chain network will exhibit a lower carbon footprint and thus are more environmentally friendly.

Contrary to the proposed influence of the centrality of the organization on the adoption of sustainable practices, we argue that organizations with high betweenness centrality (centrality in the network) will perform better on environmental performance. Unlike the dampening effect of a high network centrality on stakeholder pressure, network centrality will increase the pressure on focal organizations to improve environmental performance. Being the key actor in the SCN, such organizations have a central role in the supply chain network, often due to the access to critical resources, or organizational size. These organizations are expected to lead in improving environmental performance. Thus, we propose that organizations with high betweenness centrality are more environmentally friendly. This perspective integrates the rationale based on the institutional theory lens with network characteristics. Contrary to the prior research that argues for greater power for organizations with high betweenness centrality resulting in the capability to withstand pressure from the stakeholders, we propose that this characteristic in turn makes the organizations more vulnerable to stakeholder pressure, as they might be seen as the organization with prowess and capability to improve their environmental performance. Thus, an organization's central position in a network yields power, which drives environmental performance, resulting in increased pressure and expectations from them.

Method

Aviation Sector

The aircraft market is primarily a duopoly (Data monitor 2008) with Boeing and Airbus being the two largest manufacturing organizations in the space. Embraer is a competitor to Boeing and Airbus. This paper focuses on Boeing and EADS (the parent company of Airbus). Boeing is the largest aerospace organization (Boeing 2013). Given the small population size, when we focus on these organizations, we focus on the entire universe and hence are able to investigate our research questions in its entirety. However, the number of suppliers and customers involved are sufficiently large to delineate the role of network characteristics in environmental sustainability.

Data

We rely on a corporate subscription-based database to provide information on the major suppliers, customers, and peers for the organization. The database also provides information on the various environmental performance metrics for the organizations. One common environmental performance metric is carbon performance (Busch and Hoffman 2011). In this study, we use different measures of carbon performance: CO_2 intensity per sale, CO_2 intensity per EBIDTA, CO_2 intensity per energy, CO_2 intensity per employee, and CO_2 intensity per asset.

Further, we use resource usage based measures such as the energy intensity per sale, energy intensity per EBIDTA, energy intensity per employee, energy intensity per asset, water intensity per sale, water intensity per EBIDTA, water intensity per energy, water intensity per employee, and water intensity per asset. The use of intensity measures rather than the absolute measures controls for the increase in emissions and resource usage due to an increase in economic activity. Organizations are expected to increase their output level, and the emissions and resources used

often increase due to the increase in the output level. However, if emissions and the resources used decrease when an additional unit of output is produced, it indicates that an organization is becoming more environmentally friendly. Intensity measures are a ratio of emissions/resource used to the output level, and are therefore better environmental performance metrics compared to absolute measures.

Analysis

The corporate database lists Boeing, and Airbus, as the peers. This provides support for our sample. We examine the suppliers and customers of our sampled organizations to construct the network. From this approach, we can capture the complexities associated with the supply chain network of aircraft manufacturers. Further, this approach helps to keep the supply chain network of manufacturers as distinct as possible from each other, as there is potential for interlocking relationships as we delve deeper into the network. We use the current suppliers and customers' data. Aircraft manufacturing is a technology intensive sector that involves sophisticated technology and takes 2-3 years to deliver the product. Therefore, we assume that the network structure is relatively stable, and our supply chain network structure can help us to examine the influence of network characteristics on environmental performance reported in the past few years.

We use nodeXL to construct the network graph for our sampled organizations. We define betweenness as the centrality measure; it refers to the number of times, an organization lies in the path between two other organizations (Freeman 1979). We define density as the ratio of the number of edges in the network graph to the possible number of edges when all the vertices in the graph are connected to each other.

Result

Comparison of Networks

The network graphs of the tier 1 supply network for Boeing, EADS and their network characteristics are shown in Figures 1 and 2 respectively. Figure 3 shows the aircraft manufacturers' tier 1 suppliers network. The predominantly duopolistic nature of the sector potentially results in interlocking relationships between the different suppliers and customers as evident in Figure 3. The estimates for the network characteristics (see Table 2) suggest that the two networks (Boeing and EADS) are quite similar in terms of the density. However, they differ from each other in terms of the average betweenness centrality. The average betweenness centrality for EADS's network is higher compared to Boeing's while the density for Boeing's network is marginally higher compared to EADS's network.

Figure 1 – Boeing Tier 1 Network

Figure 2 – EADS Tier 1 Network

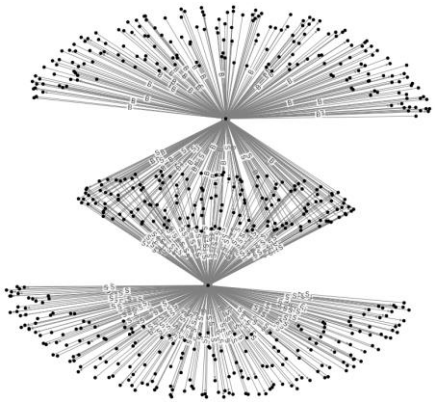

Figure 3– Aircraft Manufacturers Tier 1 Network

Table 1– Aircraft Tier 1 Supplier Network Characteristics

Average Betweenness Centrality	861.033
Graph Density	0.0023

Comparison of Environmental Performance

Table 2 – Comparison of Environmental Performance

	Definition	Boeing	EADS
Average Betweenness Centrality		361.005	374.005
Graph Density		0.00278	0.00271
CO_2 intensity per sale	Tons of CO_2 emitted per million dollars of sales revenue	19.44	**15.33 (16.85)**
CO_2 intensity per EBIDTA	Metric tonnes of CO_2 emitted per million of earnings before interest, taxes, depreciation and amortization (EBITDA)	**186.79**	237.41 (308.44)
CO_2 intensity per energy	Tonnes of CO_2 emitted by the company per megawatt-hour of energy	0.35	**0.19 (0.24)**
CO_2 intensity per employee	Metric tonnes of CO_2emitted per employee	**7.79**	7.88 (8.41)
CO_2 intensity per asset	Metric tons of CO_2 emitted per million of assets	18.23	**8.51 (9.27)**
Energy intensity per sale	Megawatt hours of energy consumed per million of sales revenue	**55.96**	81.24 (70.29)
Energy intensity per EBIDTA	Megawatt hours of energy consumed per million EBITDA	**537.74**	1257. 90 (1286.32)
Energy intensity per employee	Megawatt hours of energy consumed per employee	**22.42**	41.75 (35.06)
Energy intensity per asset	Energy consumed per million of assets	52.48	**45.11 (38.66)**
Water intensity per sale	Cubic meters of water consumed per million of sales	95.96	**73.43 (87.92)**
Water intensity per EBIDTA	Cubic meters of water consumed per million of EBITDA	**922.07**	1136.89 (1608.96)
Water intensity per energy	Cubic meters of water consumed per megawatt hour of energy	1.71	**0.90 (1.25)**
Water intensity per employee	Cubic meters of water consumed per employee	38.45	**37.73 (43.85)**

Notes: The numbers reported are the most recent available numbers for specific organizations. Numbers in bracket are for the same year across the organizations (2010). All the financial figures are converted to USD for comparison. EADS is better on 7 metrics, while Boeing is better on 6 metrics.

In this paper, we examine the influence of network characteristics on the environmental performance of the focal organization. Therefore, we have only two networks and environmental performance of two focal organizations. The small sample size makes any statistical analysis

difficult. However, we can compare the environmental performance to explore if the different network characteristics are salient in environmental performance. The environmental performance data (see Table 2) show that while the EADS (with high betweenness centrality) is better in terms of CO_2 intensity per sale, and per energy, it is worse off on *CO_2 intensity per employee and CO_2 intensity per EBIDTA.* EADS is also relatively worse on the energy intensity metrics such as energy intensity per sales, per EBIDTA, but better on most water based metrics.

Discussion

Our comparison suggests that it is quite possible that different network characteristics have a distinct impact on the different environmental performance metrics. Both the networks are quite similar in terms of density, but differ on the betweenness centrality. Despite the similarity in density, one organization is relatively better on some environmental metrics. Therefore, we conjecture that betweenness centrality rather than density might be salient in environmental performance. The betweenness centrality seems to have a distinct impact on the different environmental performance metrics. While the high betweenness centrality seems to positively influence emissions, and water related metrics, the energy related metrics are worse off for EADS which has high betweenness centrality. Moreover, organization with high betweenness centrality is worse off in terms of environmental performance metrics based on EBIDTA. The earnings based metrics are susceptible to the operational strategy. Boeing has often focused on the smaller aircraft. The better performance of Boeing on the EBIDTA based measures suggests that small aircraft manufacturing is more environmentally friendly.

Limitations

Our study has three key limitations. First, the analysis includes only the tier 1 suppliers and customers. Thus, our supply chain network is at best a higher level representation of the supply chain network of our sampled organizations. Further, our network is based on the suppliers and customers reported in the corporate database. It is quite possible that there may be small suppliers which are not reported in the database. Second, the sampled organizations for our study are from a technology intensive sector, where even the customers are often organizations. The inferences from such a sample may not be generalizable. Third, due to the small sample size, we could not conduct any rigorous statistical nor econometric analysis.

Conclusion

We conduct ***an exploratory study*** to examine if there is any relationship between supply chain network characteristics and environmental performance. Specifically, we examine if the organizations in a dense supply chain network are environmentally friendly. Our research suggests the presence of such relationships for aircraft manufacturing organizations. Future research can extend the extant research for a sophisticated and deeper examination of supply chain networks and associated emissions.

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