Environmental and Cost Synergy in Supply Chain Network Integration in Mergers and Acquisitions

Anna Nagurney
John F. Smith Memorial Professor
and
Trisha Woolley
Isenberg School of Mangement
University of Massachusetts
Amherst, Massachusetts 01003

Department of Mathematics and Computer Sciences at the University of Catania, Italy, Fulbright Senior Specialist Workshop Lecture

Wednesday, March 12, 2008: 9:00 – 9:40

Firms and the Environment

- Pollution has major adverse consequences including global warming, acid rain, rising oceanic temperatures, smog, and the resulting harmful effects on wildlife and human health.
- Firms, in turn, are increasingly realizing the importance of their environmental impacts and the return on the bottom line for those actions expended to reduce pollution (Hart and Ahuja (1996)).
- For example:
  - ◇ 3M saved almost $500 million by implementing over 3000 projects that have reduced emissions by over 1 billion pounds since 1975 (Walley and Whitehead (1994)).
  - ◇ DuPont, has the equivalent of 35% of its share price invested in capital and operating expenditures related to protecting the environment. A 15% improvement in efficiency, for instance, could yield nearly $3 per share (Walley and Whitehead (1994)).

Firms and the Environment

- Firms in the public eye have not only met, but exceeded, the required environmental mandate (Lyon (2003)).
  - In the U.S., over 1,200 firms voluntarily participated in the EPA's 33/50 program, agreeing to reduce certain chemical emissions 50% by 1995 (Arora and Cason (1996)).
- Customers and suppliers will punish polluters in the marketplace that violate environmental rules. Polluters may face lower profits, also called a "reputational penalty," which will be manifested in a lower stock price for the company (Klein and Leffler (1981), Klassen and McLaughlin (1996)).
  - Roper Starch Worldwide (1997) noted that more than 75% of the public will switch to a brand associated with the environment when price and quality are equal.
  - Nearly 60% percent of the public favors organizations that support the environment (Roper Starch Worldwide (1997)).

Merger Activity

- In the first 9 months of 2007, according to Thomson Financial, worldwide merger activity hit $3.6 trillion, surpassing the total from all of 2006 combined (Wong (2007)).
- Successful mergers can add tremendous value; however, the failure rate is estimated to be between 74% and 83% (Devero (2004)).
- It is worthwhile to develop tools to better predict the associated strategic gains, which include, among others, cost savings (Eccles, Lanes, and Wilson (1999)).
- A successful merger depends on the ability to measure the anticipated synergy of the proposed merger (cf. Chang (1988)).

Developing Countries and the Environment

- With the growing investment and industrialization in developing nations, it is also important to evaluate the overall impact of merger activities at not only the operational level, but also as related to environmental impacts.
- There is enormous potential for developing countries to adopt cleaner production, given current technologies as well as the levels of private capital investments.
- For example, between 1988-1995, multinational corporations invested nearly $422 billion worth of new factories, supplies, and equipment in these countries (World Resources Institute (1998)).

Developing Countries and the Environment

- Through globalization, firms of industrialized nations can acquire those firms in developing nations that offer lower production costs; however, more than not, combined with inferior environmental concerns.
- As a result of the industrialization of developing countries, the actions taken today will greatly influence the future scale of environmental and health problems.

Literature

- Farrell and Shapiro (1990) used a Cournot oligopoly model to demonstrate that when synergistic gains are possible through post-merger economies of scale, it is in consumer interests that price does not increase (also see Stennek (2003)).
- Spector (2003) shows that the failure to generate synergies from any profitable Cournot merger must raise prices, even if large-scale entry or the avoidance of a fixed cost is possible.
- Farrel and Shapiro (2001) also study synergy effects related to cost savings related to economies of scale, competition, and consumer welfare that could only be obtained post-merger. They specifically claim that direct competition has an impact on merger-specific synergies.

Literature

- Soylu et al. (2006) analyzed synergy among different energy systems using a multi-period, discrete-continuous mixed integer linear program (see also Xu (2007)).
- Lambertini and Mantovani (2007) conclude that horizontal mergers can contribute to reduce negative externalities related to the environment.
- According to Stanwick and Stanwick (2002), if environmental issues are ignored the value of the proposed merger can be greatly compromised.

Transportation Literature

- There is virtually no literature to-date that discusses the relationship between post-merger operational synergy and the effects on the environment and, thus, ultimately, society. We attempt to address this issue from a quantitative perspective.
- We develop a multicriteria decision-making optimization framework that not only minimizes costs but also minimizes emissions.
- Multicriteria decision-making has been recently much-explored as related to the transportation network equilibrium problem.

Transportation Literature

- Nagurney, Dong, and Mokhtarian (2002) include the weighting of travel time, travel cost, and the emissions generated.
- For general references on transportation networks and multicriteria decision-making, see Nagurney and Dong (2002).
- Multicriteria decision-making within a supply chain has assisted in the production and delivery of products by focusing on factors such as cost, quality, and lead times (Talluri and Baker (2002)).
- Dong, Zhang, and Nagurney (2002) proposed a supply chain network that included multicriteria decision-makers at each tier of the supply chain, including the manufacturing tier, the retailer tier, and the demand markets.

System View Structure

- Sarkis (2003) has demonstrated that environmental supply chain management, also referred to as the green supply chain, is necessary to address environmental concerns.
- For example, the Ford Motor company demanded that all of its 5000 worldwide suppliers with manufacturing plants obtain a third party certification of environmental management system (EMS) by 2003 (Rao (2002)).

System View Structure

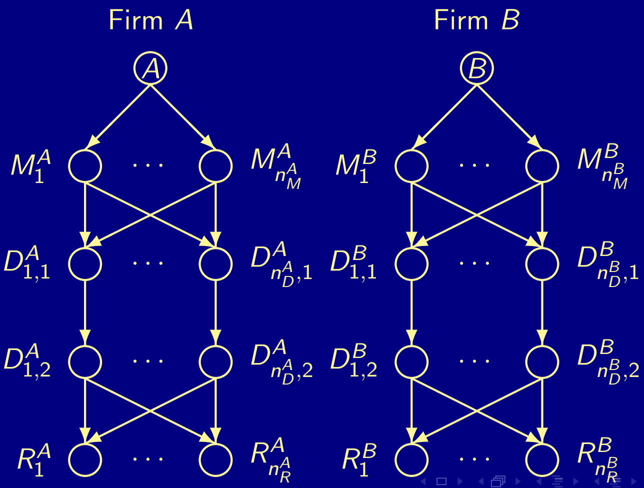
- We provide a system-optimization perspective for supply chains, a term originally coined by Dafermos and Sparrow (1969) in the context of transportation networks and corresponding to Wardrop's second principle of travel behavior with user-optimization corresponding to the first principle (Wardrop (1952)).

- Nagurney (2006), subsequently, proved that supply chain network equilibrium problems, in which there is competition among decision-makers within a tier, but cooperation between tiers, can be reformulated and solved as transportation network equilibrium problems.

Contribution

- This work is built on the recent work of Nagurney (2007) who developed a system optimization perspective for supply chain network integration in the case of horizontal mergers.
  - Nagurney, A. (2007) A System-Optimization Perspective for Supply Chain Integration: The Horizontal Merger Case. To appear in *Transportation Research E*.
- We also focus on the case of horizontal mergers (or acquisitions) and we extend the contributions in Nagurney (2007) to include multicriteria decision-making and environmental concerns.
- We analyze the synergy effects associated with a merger, in terms of the operational synergy, that is, the reduction, if any, in the cost of production, storage, and distribution, as well as the environmental benefits in terms of the reduction of associated emissions (if any).

Supply Chains of Firms A and B Prior to the Merger: Case 0



The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

Let $G_i = [N_i, L_i]$ for $i = A, B$ denote the graph consisting of nodes and directed links representing the economic activities associated with each firm i. Also let $G^0 = [N^0, L^0] \equiv \cup_{i=A,B}[N_i, L_i]$.

Following Nagurney (2007) we assume that there is a total cost associated with each link of the network corresponding to each firm i; $i = A, B$. We denote the links by a, b, etc., and the total cost on a link a by $\hat{c}_a$.

The demands for the product are assumed as given and are associated with each firm and retailer pair. Let $d_{R_k^i}$ denote the demand for the product at retailer R_k^i associated with firm i; $i = A, B$; $k = 1, \ldots, n_R^i$.

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

A path is defined as a sequence of links joining an origin node $i = A, B$ with a destination node R_k^i. Let x_p denote the nonnegative flow of the product on path p.

A path consists of a sequence of economic activities comprising manufacturing, storage, and distribution. The following conservation of flow equations must hold for each firm i:

$$\sum_{p \in P^0_{R_k^i}} x_p = d_{R_k^i}, \quad i = A, B; k = 1, \ldots, n_R^i,$$

where $P^0_{R_k^i}$ denotes the set of paths connecting (origin) node i with (destination) retail node R_k^i.

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

Let f_a denote the flow of the product on link a.

We must also have the following conservation of flow equations satisfied:

$$f_a = \sum_{p \in P^0} x_p \delta_{ap}, \quad \forall p \in P^0,$$

where $\delta_{ap} = 1$ if link a is contained in path p and $\delta_{ap} = 0$, otherwise.

Here P^0 denotes the set of *all* paths, that is, $P^0 = \cup_{i=A,B;k=1,\dots,n^i_R} P^0_{R^i_k}$.

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

Clearly, since we are first considering the two firms prior to any merger the paths associated with a given firm have no links in common with paths of the other firm.

The path flows must be nonnegative, that is,

$$x_p \geq 0, \quad \forall p \in P^0.$$

We group the path flows into the vector x.

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

The total cost on a link, be it a manufacturing/production link, a shipment/distribution link, or a storage link is assumed to be a function of the flow of the product on the link; see, for example, Nagurney (2007) and the references therein.

Hence, we have that

$$\hat{c}_a = \hat{c}_a(f_a), \quad \forall a \in L^0.$$

We assume that the total cost on each link is convex, is continuously differentiable, and has a bounded second order partial derivative.

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

We also assume that there are nonnegative capacities on the links with the capacity on link a denoted by u_a, $\forall a \in L^0$.

In addition, we assume, as given, emission functions for each economic link $a \in L^0$ and denoted by e_a, where

$$e_a = e_a(f_a), \quad \forall a \in L^0,$$

where e_a denotes the total amount of emissions generated by link a in processing an amount f_a of the product. We assume that the emission functions have the same properties as the total cost functions.

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

Since the firms, pre-merger, have no links in common, their individual cost minimization problems can be formulated jointly as follows:

$$\text{Minimize} \quad \sum_{a \in L^0} \hat{c}_a(f_a)$$

subject to the constraints presented earlier and

$$f_a \leq u_a, \quad \forall a \in L^0.$$

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

In addition, since we are considering multicriteria decision-making with environmental concerns, the minimization of emissions generated can, in turn, be expressed as follows:

$$\text{Minimize} \quad \sum_{a \in L^0} e_a(f_a)$$

subject to the constraints presented earlier and

$$f_a \leq u_a, \quad \forall a \in L^0.$$

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

We now construct a weighted total cost function, which we refer to as the generalized total cost (cf. Fishburn (1970), Chankong and Haimes (1983), Yu (1985), Keeney and Raiffa (1992), Nagurney and Dong (2002)), associated with the two criteria faced by each firm with the weight associated with total cost minimization being set equal to 1.

Specifically, for notational convenience and simplicity, we define nonnegative weights associated with the firms $i = A, B$ and links $a \in L_i$, as follows: $\alpha_{ia} \equiv 0$ if link $a \notin L_i$ and $\alpha_{ia} = \alpha_i$, otherwise, where α_i is decided upon by the decision-making authority of firm i.

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

Consequently, the multicriteria decision-making problem, pre-merger, can be expressed as:

$$\text{Minimize} \quad \sum_{a \in L^0} \sum_{i=A,B} \hat{c}_a(f_a) + \alpha_{ia} e_a(f_a)$$

subject to the constraints presented earlier and

$$f_a \leq u_a, \quad \forall a \in L^0.$$

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

Observe that this problem is, as is well-known in the transportation literature (cf. Beckmann, McGuire, and Winsten (1956), Dafermos and Sparrow (1969)), a *system-optimization* problem but in *capacitated* form and with multicriteria decision-making; see also Patriksson (1994), Nagurney (2000, 2006b), and the references therein.

Under the above imposed assumptions, the optimization problem is a convex optimization problem. If we further assume that the feasible set underlying the problem represented by the constraints is non-empty, then it follows from the standard theory of nonlinear programming (cf. Bazaraa, Sherali, and Shetty (1993)) that an optimal solution exists.

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

Let $\mathcal{K}^0$ denote the set where
$\mathcal{K}^0 \equiv \{f | \exists x \geq 0$, and the constraints hold$\}$, where f is the vector of link flows.

Also, associate the Lagrange multiplier β_a with constraint

$$f_a \leq u_a, \quad \forall a \in L^0$$

for link a and denote the associated optimal Lagrange multiplier by β_a^*. This term may also be interpreted as the price or value of an additional unit of capacity on link a.

Theorem

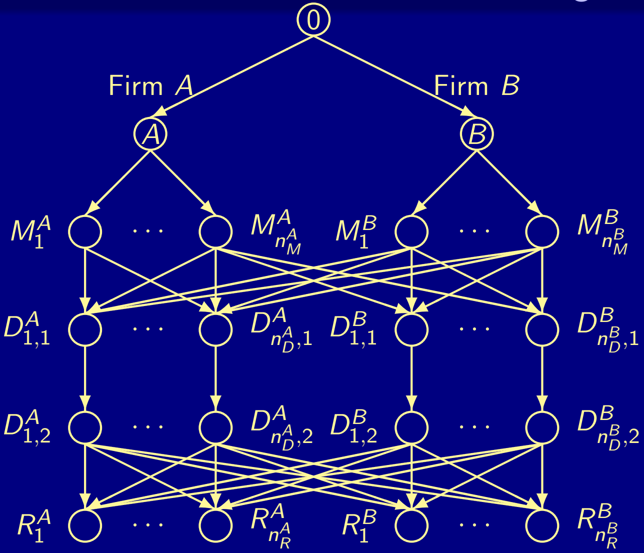
The vector of link flows $f^{*0} \in \mathcal{K}^0$ is an optimal solution to the pre-merger problem if and only if it satisfies the following variational inequality problem with the vector of nonnegative Lagrange multipliers β^{*0}:

$$\sum_{a \in L^0} \sum_{i=A,B} [\frac{\partial \hat{c}_a(f_a^*)}{\partial f_a} + \alpha_{ia} \frac{\partial e_a(f_a^*)}{\partial f_a} + \beta_a^*] \times [f_a - f_a^*]$$

$$+ \sum_{a \in L^0} [u_a - f_a^*] \times [\beta_a - \beta_a^*] \geq 0$$

$$\forall f \in \mathcal{K}^0, \forall \beta_a \geq 0, \forall a \in L^0$$

Supply Chain Network after Firms A and B Merge: Case 1



The Post-merger Multicriteria Decision-making Optimization Problem (Case 1)

We refer to the network underlying this merger as $G^1 = [N^1, L^1]$.

We associate total cost functions and emission functions with the new links.

We assume, for simplicity, that the corresponding functions on the links emanating from the supersource node are equal to zero.

The Post-merger Multicriteria Decision-making Optimization Problem (Case 1)

A path p now originates at the node 0 and is destined for one of the bottom retail nodes.

Let x_p now in the post-merger network configuration denote the flow of the product on path p joining (origin) node 0 with a (destination) retailer node.

Then the following conservation of flow equations must hold:

$$\sum_{p \in P^1_{R^i_k}} x_p = d_{R^i_k}, \quad i = A, B; k = 1, \ldots, n^i_R,$$

where $P^1_{R^i_k}$ denotes the set of paths connecting node 0 with retail node R^i_k.

The Post-merger Multicriteria Decision-making Optimization Problem (Case 1)

Due to the merger, the retail outlets can obtain the product from any manufacturing plant and any distributor. The set of paths $P^1 \equiv \cup_{i=A,B;k=1,\ldots,n^i_R} P^1_{R^i_k}$.

In addition, as before, we let f_a denote the flow of the product on link a. Hence, we must also have the following conservation of flow equations satisfied:

$$f_a = \sum_{p \in P^1} x_p \delta_{ap}, \quad \forall p \in P^1.$$

Of course, we also have that the path flows must be nonnegative, that is,

$$x_p \geq 0, \quad \forall p \in P^1.$$

The Post-merger Multicriteria Decision-making Optimization Problem (Case 1)

We assume, again, that the links representing the manufacturing activities, the shipment, and the storage activities possess nonnegative capacities, denoted as u_a, $\forall a \in L^1$. This can be expressed as

$$f_a \leq u_a, \quad \forall a \in L^1.$$

We assume that, post-merger, the weight associated with the environmental emission cost minimization criterion is denoted by α and this weight is nonnegative.

This is reasonable since, unlike in the pre-merger case, the firms are now merged into a single decision-making economic entity and there is now a single weight associated with the emissions generated.

The Post-merger Multicriteria Decision-making Optimization Problem (Case 1)

The post-merger optimization problem is concerned with total cost minimization as well as the minimization of emissions.

The following multicriteria decision-making optimization problem must now be solved:

$$\text{Minimize} \quad \sum_{a \in L^1} [\hat{c}_a(f_a) + \alpha e_a(f_a)]$$

subject to the constraints described earlier.

Note that L^1 represents all links in the post-merger network belonging to firm A and to firm B.

The Post-merger Multicriteria Decision-making Optimization Problem (Case 1)

There are distinct options for the weight α and we explore several in the concrete numerical examples.

Specifically, in the case that the merger/acquisition is an environmentally hostile one, then we may set $\alpha = 0$.

In the case that it is environmentally conscious, then α may be set to 1; and so on, with α being a function of the firms' pre-merger weights also a possibility.

The Post-merger Multicriteria Decision-making Optimization Problem (Case 1)

The solution to the post-merger multicriteria decision-making optimization problem subject to the described constraints can also be obtained as a solution to a variational inequality problem where $a \in L^1$.

α is substituted for α_i, and the vectors: f, x, and β have identical definitions as before, but are re-dimensioned/expanded accordingly.

Finally, instead of the feasible set $\mathcal{K}^0$ we now have $\mathcal{K}^1 \equiv \{f | \exists x \geq 0, \text{ and the poster merger constraints hold}\}$. We denote the solution to the variational inequality problem governing Case 1 by f^{*1}, β^{*1}.

Theorem

The vector of link flows $f^{*1} \in \mathcal{K}^1$ is an optimal solution to the post-merger problem if and only if it satisfies the following variational inequality problem with the vector of nonnegative Lagrange multipliers β^{*1}:

$$\sum_{a \in L^1} [\frac{\partial \hat{c}_a(f_a^*)}{\partial f_a} + \alpha \frac{\partial e_a(f_a^*)}{\partial f_a} + \beta_a^*] \times [f_a - f_a^*] + \sum_{a \in L^1} [u_a - f_a^*] \times [\beta_a - \beta_a^*] \geq 0,$$

$$\forall f \in \mathcal{K}^1, \forall \beta_a \geq 0, \forall a \in L^1$$

1. Motivation
2. Literature
3. Models
4. **Measures**
5. Numerical Examples
6. Conclusion

Quantifying Synergy Associated with Multicriteria Decision-Making Firms with Environmental Concerns in Mergers/Acquisitions

- We define the total generalized cost TGC^0 associated with the pre-merger problem, or Case 0 as the value of the pre-merger objective function evaluated at its optimal solution f^{*0}.
- We define the total generalized cost TGC^1 associated with the post-merger problem, or Case 1, as the value of the post-merger objective function evaluated at its optimal solution f^{*1}.
- These flow vectors we obtain from the solutions of the variational inequalities for the pre and post merger cases, respectively.

Quantifying Synergy Associated with Multicriteria Decision-Making Firms with Environmental Concerns in Mergers/Acquisitions

The synergy associated with the total generalized costs which captures both the total costs and the weighted total emissions is denoted by $\mathcal{S}^{TGC}$ and is defined as follows:

$$\mathcal{S}^{TGC} \equiv [\frac{TGC^0 - TGC^1}{TGC^0}] \times 100\%$$

Quantifying Synergy Associated with Multicriteria Decision-Making Firms with Environmental Concerns in Mergers/Acquisitions

- We define TC^0 as the total costs generated under solution f^{*0}.
- We define TC^1 as the total costs generated under solution f^{*1}.

Quantifying Synergy Associated with Multicriteria Decision-Making Firms with Environmental Concerns in Mergers/Acquisitions

We can also measure the synergy by analyzing the total costs pre and post the merger (cf. Eccles, Lanes, and Wilson (1999) and Nagurney (2007)), as well as the changes in emissions. For example, the synergy based on total costs and proposed by Nagurney (2007), but not in a multicriteria decision-making context, which we denote here by $\mathcal{S}^{TC}$, can be calculated as the percentage difference between the total cost pre *vs* the total cost post merger:

$$\mathcal{S}^{TC} \equiv [\frac{TC^0 - TC^1}{TC^0}] \times 100\%$$

Quantifying Synergy Associated with Multicriteria Decision-Making Firms with Environmental Concerns in Mergers/Acquisitions

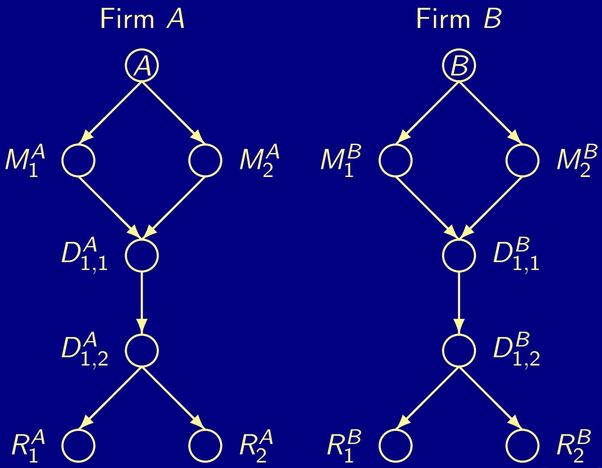
- We define TE^0 as the total emissions generated under solution f^{*0}.
- We define TE^1 as the total emissions generated under solution f^{*1}.

Quantifying Synergy Associated with Multicriteria Decision-Making Firms with Environmental Concerns in Mergers/Acquisitions

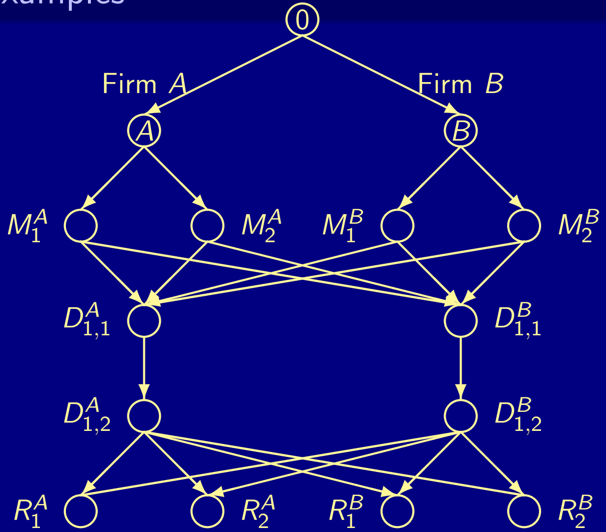
The environmental impacts related to the relationship between pre and post merger emission levels can also be calculated using a similar measure as that of the total cost. Towards that end we also define the total emissions synergy, denoted by $\mathcal{S}^{TE}$ as:

$$\mathcal{S}^{TE} \equiv [\frac{TE^0 - TE^1}{TE^0}] \times 100\%$$

Pre-Merger Supply Chain Network Topology for the Numerical Examples



Post-Merger Supply Chain Network Topology for the Numerical Examples



Definition of the Links and the Associated Emission Functions for the Numerical Examples

Link a	From Node	To Node	Ex. 1,4: $e_a(f_a)$	Ex. 2,3: $e_a(f_a)$
1	A	M_1^A	$10f_1$	$5f_1$
2	A	M_2^A	$10f_2$	$5f_2$
3	M_1^A	$D_{1,1}^A$	$10f_3$	$5f_3$
4	M_2^A	$D_{1,1}^A$	$10f_4$	$5f_4$
5	$D_{1,1}^A$	$D_{1,2}^A$	$10f_5$	$5f_5$
6	$D_{1,2}^A$	R_1^A	$10f_6$	$5f_6$
7	$D_{1,2}^A$	R_2^A	$10f_7$	$5f_7$
8	B	M_1^B	$10f_8$	$10f_8$
9	B	M_2^B	$10f_9$	$10f_9$
10	M_1^B	$D_{1,1}^B$	$10f_{10}$	$10f_{10}$
11	M_2^B	$D_{1,1}^B$	$10f_{11}$	$10f_{11}$
12	$D_{1,1}^B$	$D_{1,2}^B$	$10f_{12}$	$10f_{12}$
13	$D_{1,2}^B$	R_1^B	$10f_{13}$	$10f_{13}$
14	$D_{1,2}^B$	R_2^B	$10f_{14}$	$10f_{14}$
15	M_1^A	$D_{1,1}^B$	$10f_{15}$	$5f_{15}$
16	M_2^A	$D_{1,1}^B$	$10f_{16}$	$5f_{16}$
17	M_1^B	$D_{1,1}^A$	$10f_{17}$	$10f_{17}$
18	M_2^B	$D_{1,1}^A$	$10f_{18}$	$10f_{18}$
19	$D_{1,2}^A$	R_1^B	$10f_{19}$	$5f_{19}$
20	$D_{1,2}^A$	R_2^B	$10f_{20}$	$5f_{20}$
21	$D_{1,2}^B$	R_1^A	$10f_{21}$	$10f_{21}$
22	$D_{1,2}^B$	R_2^A	$10f_{22}$	$10f_{22}$

Numerical Example 1

The total cost functions were: $\hat{c}_a(f_a) = f_a^2 + 2f_a$ for all links a pre-merger and post-merger in all the numerical examples, except for the links post-merger that join the node 0 with nodes A and B.

By convention, these merger links had associated total costs equal to 0.

The weights: $\alpha_{ia} = \alpha_i$ were set to 1 for both firms $i = A, B$ and for all links $a \in L^0$. Thus, we assumed that each firm is equally concerned with cost minimization and with emission minimization.

The pre-merger solution f^{*0} for both firms had all components equal to 5 for all links except for the storage links, which had flows of 10.

Numerical Example 1

The associated β^{*0} had all components equal to 0, since the flow on any particular link did not meet capacity.

The total cost was 660.00, the total emissions generated was 800.00 and the total generalized cost was 1460.00.

Post-merger, for each firm, the cost and emission functions were again set to $\hat{c}_a(f_a) = f_a^2 + 2f_a$ and $e_a(f_a) = 10f_a$, respectively, including those links formed post-merger.

The demand at each retail market was kept at 5 and the capacity of each link, including those formed post-merger, was set to 15.

The weight α, post-merger, was set to 1.

Numerical Example 1

For both firms, the manufacturing link flows were 5; 2.5 was the shipment between each manufacturer and distribution center, 10 was the flow representing storage at each distribution center, and 2.5 was the flow from each distribution/storage center to each demand market.

The vector of optimal multipliers, β^{*1}, post-merger, had all its components equal to 0.

The total cost was 560.00, the total emissions generated were 800.00, and the total generalized cost was 1360.00.

There were total cost synergistic gains, $S^{TC} = 15.15\%$, yet no environmental gains, since $S^{TE} = 0.00\%$. Additionally, the total generalized cost synergy was: $S^{TGC} = 6.85\%$.

Numerical Example 2

Example 2 was constructed from Example 1 but with the following modifications. Pre-merger, the emission functions of firm A were reduced from $e_a(f_a) = 10f_a$ to $e_a(f_a) = 5f_a$, $\forall a \in L^0$. Hence, firm A now is assumed to produce fewer emissions as a function of flow on each link than firm B.

Additionally, pre-merger, the environmental concern of firm B was reduced to zero, that is, $\alpha_{Ba} = 0$, for all links a associated with firm B, pre-merger.

Hence, not only does firm A emit less as a function of the flow on each link, but firm A also has a greater environmental concern than firm B.

Numerical Example 2

Pre-merger, the optimal solution f^{*0} was identical to that obtained, pre-merger, for Example 1. The total cost was 660.00, the total emissions generated were 600.00, and the total generalized cost was 860.00. The components of β^{*0} were the same as in Example 1.

Post-merger, the emission functions of firm A were as above and $e_a(f_a) = 5f_a$, on all links formed post-merger, and emanating from the original firm A; the analogous links for firm B had emission functions $e_a(f_a) = 10f_a$.

We assumed an amicable merger. In particular, post-merger, we assumed that $\alpha = 0.5$.

Numerical Example 2

The optimal flow from node A to each manufacturer was 5.83, the optimal shipment from each original A's manufacturer to original A's distribution center was 3.12, while the distribution to B's distribution center was 2.71.

Storage for firm A possessed a flow of 10.83 and A shipped from its own distribution/storage center to its own as well as the retail markets of firm B in the amount of 2.71.

For firm B, the optimal flow from node B to its manufacturing facilities was 4.16, with a shipment to its own distribution center of 1.87, and 2.29 to A's distribution center.

The flow at B's original distribution/storage center was 9.16. Finally, the flow shipped from the original B to each retail outlet from its distribution/storage center was 2.29.

Numerical Example 2

The total cost was now 565.65, the total emissions generated were equal to 574.63, and the total generalized cost was now 852.97.

The synergies were: $S^{TC} = 14.30\%$ for the total cost, $S^{TE} = 4.23\%$ for the total emissions, and $S^{TGC} = 0.82\%$ for the total generalized cost.

As compared to Ex. 1, even though cost synergies decreased by 0.85%, total emission synergies increased by 4.23%, & the total generalized cost synergy decreased by 6.03%.

Numerical Example 2

In the event of an amicable merger between firms that have different environmental concerns & activities to reduce emissions, there was an increase in emission synergy.

There was a tradeoff between operational synergy gains with environmental benefits. As environmental benefits are increased, operational synergy decreased, even though, not quite as significantly as the environmental gains to society.

The total generalized cost synergy decreased even more drastically than the environmental gains which signifies the influential effect environmental concerns had on the objective of the firm *pre & post* merger.

Numerical Example 3

Example 3 was constructed from Example 2 but we now assumed that the merger was hostile, but with firm B as the dominant firm, that is, the post environmental concern will be like that of firm B. Hence, $\alpha = 0$.

The pre-merger results are the same as in Example 2. For the post-merger results, the flows were symmetric for each original firm, with a flow of 5 from each manufacturer, a shipment of 2.50 to each distribution center with a flow of 10 in the storage center, and a product shipment of 2.50 to each retail outlet.

The total cost was 560.00, the total emissions generated were 600.00, and the total generalized cost was 560.00.

Thus, the synergy results were 15.15% for the total cost, 0.00% for the total emissions, and 34.88% for the total generalized cost.

Numerical Example 3

It is of notable interest that the total cost synergy and the total emission synergy are identical to those obtained for Example 1.

However, the total generalized cost synergy in this example was significantly higher. In Example 1, both firms showed concern for the environment *pre* and *post* merger, with $\alpha_{Aa} = \alpha_{Ba} = 1$, for all links a associated with firm A and firm B pre-merger.

In this example, firm B showed no concern for the environment pre-merger, and as the dominant firm, post-merger, $\alpha = 0$. So even though there was no benefit, environmentally, and no difference in total cost, there were significant gains in terms of the total generalized cost of the merged firm.

Numerical Example 4

Example 4 was constructed from Example 1 but with the following modifications.

Pre-merger, we assumed that firm A is environmentally conscious, that is $\alpha_{Aa} = 1$ for firm $i = A$ and for all links a associated with firm A, while firm B does not display any concern for the environment, that is, $\alpha_{Ba} = 0$ for all its links.

Additionally, we now assumed that the merger was hostile with firm A as the dominant firm, that is, firm A imposes its environmental concern on firm B. We assumed that, post-merger, $\alpha = 1$. The pre-merger optimal flows are the same as in Example 1. The total cost was 660.00, the total emissions generated were 800.00, and the total generalized cost was 1060.00.

Numerical Example 4

The post-merger results were as follows. The optimal link flows were identical to those obtained for Example 3, post-merger. The total cost was 560.00, the total emissions generated were 800.00, and the total generalized cost was 1360.00.

The synergy results were: 15.15% for the total cost; 0.00% for the total emissions, and −28.30% for the total generalized cost.

When the dominant firm in the proposed merger was more concerned with the environmental impacts, the overall total generalized cost synergy was the lowest.

This example illustrates the importance of not only demonstrating concern for the environment but also to take action in order to reduce the emission functions.

Pre-Merger Solutions to the Numerical Examples

Link a	From Node	To Node	Ex. 1 - 4: f_a^*
1	A	M_1^A	5.00
2	A	M_2^A	5.00
3	M_1^A	$D_{1,1}^A$	5.00
4	M_2^A	$D_{1,1}^A$	5.00
5	$D_{1,1}^A$	$D_{1,2}^A$	10.00
6	$D_{1,2}^A$	R_1^A	5.00
7	$D_{1,2}^A$	R_2^A	5.00
8	B	M_1^B	5.00
9	B	M_2^B	5.00
10	M_1^B	$D_{1,1}^B$	5.00
11	M_2^B	$D_{1,1}^B$	5.00
12	$D_{1,1}^B$	$D_{1,2}^B$	10.00
13	$D_{1,2}^B$	R_1^B	5.00
14	$D_{1,2}^B$	R_2^B	5.00

Post-Merger Solutions to the Numerical Examples

Link a	From Node	To Node	Ex. 1: f_a^*	Ex. 2: f_a^*	Ex 3: f_a^*	Ex. 4: f_a^*
1	A	M_1^A	5.00	5.83	5.00	5.00
2	A	M_2^A	5.00	5.83	5.00	5.00
3	M_1^A	$D_{1,1}^A$	2.50	3.12	2.50	2.50
4	M_2^A	$D_{1,1}^A$	2.50	3.12	2.50	2.50
5	$D_{1,1}^A$	$D_{1,2}^A$	10.00	10.83	10.00	10.00
6	$D_{1,2}^A$	R_1^A	2.50	2.71	2.50	2.50
7	$D_{1,2}^A$	R_2^A	2.50	2.71	2.50	2.50
8	B	M_1^B	5.00	4.16	5.00	5.00
9	B	M_2^B	5.00	4.16	5.00	5.00
10	M_1^B	$D_{1,1}^B$	2.50	1.87	2.50	2.50
11	M_2^B	$D_{1,1}^B$	2.50	1.87	2.50	2.50
12	$D_{1,1}^B$	$D_{1,2}^B$	10.00	9.16	10.00	10.00
13	$D_{1,2}^B$	R_1^B	2.50	2.29	2.50	2.50
14	$D_{1,2}^B$	R_2^B	2.50	2.29	2.50	2.50
15	M_1^A	$D_{1,1}^B$	2.50	2.71	2.50	2.50
16	M_2^A	$D_{1,1}^B$	2.50	2.71	2.50	2.50
17	M_1^B	$D_{1,1}^A$	2.50	2.29	2.50	2.50
18	M_2^B	$D_{1,1}^A$	2.50	2.29	2.50	2.50
19	$D_{1,2}^A$	R_1^B	2.50	2.71	2.50	2.50
20	$D_{1,2}^A$	R_2^B	2.50	2.71	2.50	2.50
21	$D_{1,2}^B$	R_1^A	2.50	2.29	2.50	2.50
22	$D_{1,2}^B$	R_2^A	2.50	2.29	2.50	2.50

Synergy Values for the Numerical Examples

Example	1	2	3	4
TC^0	660.00	660.00	660.00	660.00
TC^1	560.00	565.65	560.00	560.00
S^{TC}	15.15%	14.30%	15.15%	15.15%
TE^0	800.00	600.00	600.00	800.00
TE^1	800.00	574.63	600.00	800.00
S^{TE}	0.00%	4.23%	0.00%	0.00%
TGC^0	1460.00	860.00	860.00	1060.00
TGC^1	1360.00	852.97	560.00	1360.00
S^{TGC}	6.85%	0.82%	34.88%	−28.30%

Additional Examples

In addition, in order to explore the impacts of improved technologies associated with distribution/transportation we constructed the following variants of the above numerical examples.

We assumed that the pre-merger data were as in Examples 1 through 4 as were the post-merger data except that we assumed that the emission functions associated with the new "merger" links were all identically equal to 0.

Additional Examples

The synergies computed for this variant of Examples 1 through 4 suggest an inverse relationship between total cost synergy and emission synergy.

Despite the fact that variant examples one and four both have identical total cost and total emission synergies, their respective total generalized cost synergies are, nevertheless, distinct.

This can be attributed to the difference in concern for the environment pre- and post-merger.

Post-Merger Solutions to the Variant Numerical Examples

Link a	From Node	To Node	Ex. 1,4: f_a^*	Ex. 2: f_a^*	Ex. 3: f_a^*
1	A	M_1^A	5.00	5.62	5.00
2	A	M_2^A	5.00	5.62	5.00
3	M_1^A	$D_{1,1}^A$	0.00	2.08	2.50
4	M_2^A	$D_{1,1}^A$	0.00	2.08	2.50
5	$D_{1,1}^A$	$D_{1,2}^A$	10.00	10.83	9.99
6	$D_{1,2}^A$	R_1^A	0.00	1.77	2.50
7	$D_{1,2}^A$	R_2^A	0.00	1.77	2.50
8	B	M_1^B	5.00	4.37	5.00
9	B	M_2^B	5.00	4.37	5.00
10	M_1^B	$D_{1,1}^B$	0.00	1.04	2.50
11	M_2^B	$D_{1,1}^B$	0.00	1.04	2.50
12	$D_{1,1}^B$	$D_{1,2}^B$	10.00	9.16	9.99
13	$D_{1,2}^B$	R_1^B	0.00	1.35	2.50
14	$D_{1,2}^B$	R_2^B	0.00	1.35	2.50
15	M_1^A	$D_{1,1}^B$	5.00	3.54	2.50
16	M_2^A	$D_{1,1}^B$	5.00	3.54	2.50
17	M_1^B	$D_{1,1}^A$	5.00	3.64	2.50
18	M_2^B	$D_{1,1}^A$	5.00	3.64	2.50
19	$D_{1,2}^A$	R_1^B	5.00	3.33	2.50
20	$D_{1,2}^A$	R_2^B	5.00	3.33	2.50
21	$D_{1,2}^B$	R_1^A	5.00	3.23	2.50
22	$D_{1,2}^B$	R_2^A	5.00	3.23	2.50

Synergy Values for the Variant Numerical Examples

Example	1	2	3	4
TC^0	660.00	660.00	660.00	660.00
TC^1	660.00	577.89	560.00	660.00
S^{TC}	0.00%	12.44%	15.15%	0.00%
TE^0	800.00	600.00	600.00	800.00
TE^1	400.00	375.75	450.00	400.00
S^{TE}	50.00%	37.38%	25.00%	50.00%
TGC^0	1460.00	860.00	860.00	1060.00
TGC^1	1060.00	765.77	560.00	1060.00
S^{TGC}	27.40%	10.96%	34.88%	0.00%

Conclusion

- We presented a multicriteria decision-making framework to evaluate the environmental impacts associated with mergers and acquisitions.
- The framework is based on a supply chain network perspective, in a system-optimization context, that captures the economic activities of a firm such as manufacturing/production, storage, as well as distribution.

Conclusion

- We presented the pre-merger and the post-merger network models, derived their variational inequality formulations, and then defined a total generalized cost synergy measure as well as a total cost synergy measure and a total emissions synergy measure.
- The firms, pre-merger, assigned a weight representing their individual environmental concerns; post-merger, the weight was uniform.

Conclusion

- We presented several numerical examples, which, although stylized, demonstrated the generality of the approach and how the new framework can be used to assess apriori synergy associated with mergers and acquisitions and with an environmental focus.
- Specifically, we concluded that the operating economies (resulting from greater economies of scale that improve productivity or cut costs) may have an inverse impact on the environmental effects to society depending on the level of concern that each firm has for the environment and their joint actions taken to reduce emissions.

Conclusion

- To the best of our knowledge, this is the first paper to quantify the relationships associated with mergers and acquisitions and possible synergies associated with environmental emissions.
- With this paper, we can begin to further explore numerous questions associated with mergers and acquisitions, environmental synergies, as well as industrial organization.

Acknowledgements

This research was supported by the John F. Smith Memorial Fund at the Isenberg School of Management. This support is gratefully acknowledged.

Also a thank you to Professor Matthias Ehrgott, the organizer of the 19th International MCDM Conference, held January 7-12, 2008, in Auckland, New Zealand, and all the participants for many helpful and stimulating discussions which led to this paper.

Thank you!

For more information please visit
http://supernet.som.umass.edu/