Labor and Supply Chain Networks: It's All About People

Anna Nagurney

Eugene M. Isenberg Chair in Integrative Studies
Director – Virtual Center for Supernetworks
Isenberg School of Management
University of Massachusetts Amherst

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Acknowledgments

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Thanks also to the Local Organizing and the Program Committees!

Dedication

This talk is dedicated to essential workers, who have sustained us in the COVID-19 pandemic.

I also acknowledge all the freedom-loving people on the planet, including those fighting for their freedom in Ukraine.

Outline of Presentation

- **Background and Motivation**
- **Optimization and Supply Chain Network Models with Labor**
  - Food
  - Medical Supplies
- **Methodology - The Variational Inequality Problem**
- **Game Theory and Supply Chain Network Models with Labor**
  - Food and Labor Disruptions
- **Resilience of Supply Chain Networks**
- **Dealing with the Media and Impacting Policy**

Background and Motivation

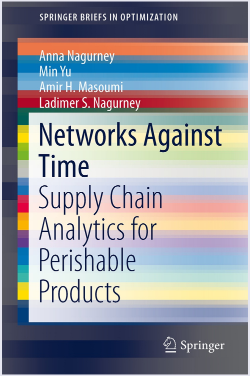
I Work on the Modeling of Network Systems

Much of My Recent Research Has Been on Supply Chains

Some of My Books

A Multidisciplinary Approach

In our research on perishable and time-sensitive product supply chains, we utilize results from physics, chemistry, biology, and medicine in order to capture the perishability of various products over time from healthcare products such as blood, medical nucleotides, vaccines and pharmaceuticals to food.



A major research theme of ours in the COVID-19 pandemic is the inclusion of labor in supply chains, using optimization and game theory. This research is also very relevant with Russia's war against Ukraine.

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NEWS FEATURES PODCASTS

January 29, 2021 in Supply Chain Networks

In the End, It's All About People

COVID-19 vaccine production reveals dependency on supply chains, labor workforce in the U.S.

By Anna Nagurney

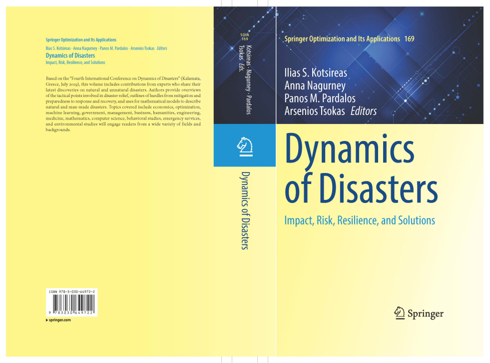
SHARE: PRINT ARTICLE: https://doi.org/10.1287/orms.2021.01.17

The COVID-19 pandemic has dramatically revealed how dependent we are on supply chains and the availability of labor. Without the human element, meatpacking plants cannot function; fresh produce cannot be picked; grocery stores cannot be shelved; PPEs cannot be produced and distributed; and products cannot be delivered to our homes through e-commerce. Also, COVID-19 vaccine production may lack the human resources to ensure product quality and efficacy, as well as its distribution and ultimate administration into our arms. Without healthcare workers to administer COVID-19 vaccines, the battle against the coronavirus cannot be won. Many hospitals are already short-staffed because of the pandemic.

Optimization and Supply Chain Network Models with Labor

Research and Publications

"Perishable Food Supply Chain Networks with Labor in the Covid-19 Pandemic," A. Nagurney, in: *Dynamics of Disasters - Impact, Risk, Resilience, and Solutions*, **I.S. Kotsireas, A. Nagurney, P.M. Pardalos, and A. Tsokas, Editors, Springer Nature Switzerland AG, 2021, pp 173-193.**



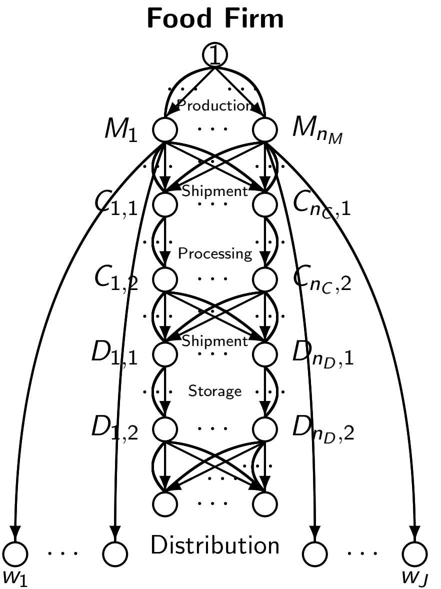


Figure: The Perishable Food Supply Chain Network Topology

Our findings include:

1. **The lack of labor on a single link, even a freight one, may significantly negatively impact a food firm.**
2. **Preserving productivity in all utilized supply chain network economic activities is critical** since the impact of a drastic reduction can severely reduce profits.
3. **Adding more direct sales, whether at farmers' markets or nearby farm stands, may help a food firm in a pandemic.**
4. Also, if a firm **enhances its marketing** so as to have consumers be willing to pay a higher price for its fresh produce, **major profit increases can occur**.

This Research Is Highly Relevant to the War On Ukraine

On February 24, 2022, Russia began a major invasion of Ukraine, a sovereign, democratic nation.

• Ukraine is the breadbasket of the world with major exports of wheat, corn, barley, and sunflower oil. Many countries, including MENA ones (Middle Eastern and North African countries) depend on agricultural products from Ukraine.

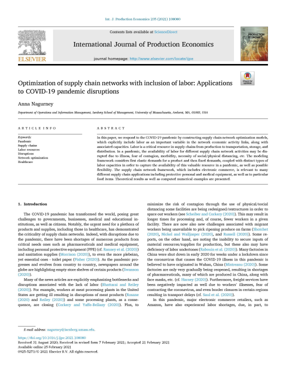
• The war has **disrupted trade due to blockages of ports on the Black Sea and the Azov Sea and the mining of seas and has affected shipping options.**

• **The price of seeds has risen, plus the prices of fuel and fertilizer.**

• Having enough labor to plant and harvest will also be challenging and getting the products to market and points of demand.

• **The World Food Programme used to buy 50% of its wheat from Ukraine.**

A. Nagurney, "Optimization of Supply Chain Networks with Inclusion of Labor: Applications to Covid-19 Pandemic Disruptions," *International Journal of Production Economics* **235 (2021), 108074.**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Optimization of supply chain networks with inclusion of labor: Applications to COVID-19 pandemic disruptions

Anna Nagurney

Department of Operations and Information Management, Isenberg School of Management, University of Massachusetts, Amherst, MA, 01003, USA

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ABSTRACT

In this paper, we respond to the COVID-19 pandemic by constructing supply chain network optimization models, which explicitly include labor as an important variable in the network economic activity links, along with associated capacities. Labor is a critical resource in supply chains from production to transportation, storage, and distribution. In a pandemic, the availability of labor for different supply chain network activities may be disrupted due to illness, fear of contagion, morbidity, necessity of social/physical distancing, etc. The modeling framework considers first elastic demands for a product and then fixed demands, coupled with distinct types of labor capacities in order to capture the availability of this valuable resource in a pandemic, as well as possible flexibility. The supply chain network framework, which includes electronic commerce, is relevant to many different supply chain applications including protective personal and medical equipment, as well as to particular food items. Theoretical results as well as computed numerical examples are presented.

1. Introduction

The COVID-19 pandemic has transformed the world, posing great challenges to governments, businesses, medical and educational institutions, as well as citizens. Notably, the urgent need for a plethora of products and supplies, including those in healthcare, has demonstrated the criticality of supply chain networks. Indeed, with disruptions due to the pandemic, there have been shortages of numerous products from critical needs ones such as pharmaceuticals and medical equipment, including personal protective equipment (PPE) (cf. Ranney et al. (2020)) and sanitation supplies (Morrison (2020)), to even the more plebeian, yet essential ones - toilet paper (Fisher (2020)). As the pandemic progresses and evolves from country to country, newspapers around the globe are highlighting empty store shelves of certain products (Swanson (2020)).

Many of the news articles are explicitly emphasizing bottlenecks and disruptions associated with the lack of labor (Bhattarai and Reiley (2020)). For example, workers at meat processing plants in the United States are getting ill resulting in disruptions of meat products (Rosane (2020) and Reiley (2020)) and some processing plants, as a consequence, are closing (Corkery and Yaffe-Bellany (2020)). Plus, to minimize the risk of contagion through the use of physical/social distancing some facilities are being redesigned/restructures in order to space out workers (see Scheiber and Corkery (2020)). This may result in longer times for processing and, of course, fewer workers in a given facility. There are now also new challenges associated with migrant workers being unavailable to pick ripening produce on farms (Shoichet (2020), Nickel and Walljasper (2020), and Russell (2020)). Some reports, on the other hand, are noting the inability to secure inputs of material resources/supplies for production, but these also may have deficiency of labor undertones (Rabouin et al. (2020)). Many factories in China were shut down in early 2020 for weeks under a lockdown since the coronavirus that causes the COVID-19 illness in this pandemic is believed to have originated in Wuhan, China (Mistreanu (2020)). Some factories are only very gradually being reopened, resulting in shortages of pharmaceuticals, many of which are produced in China, along with face masks, etc. (cf. Harney (2020)). Furthermore, freight services have been negatively impacted as well due to workers' illnesses, fear of contracting the coronavirus, and even border closures in certain regions resulting in transport delays (cf. Saul et al. (2020)).

In this pandemic, major electronic commerce retailers, such as Amazon, have also experienced labor shortages, due, in part, to

E-mail address: nagurney@isenberg.umass.edu.

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The modeling framework considers first elastic demands for a product and then fixed demands, coupled with distinct types of labor capacities in order to capture the availability of this valuable resource in a pandemic, as well as possible flexibility.

The supply chain network framework includes electronic commerce and is relevant to many different supply chain applications including protective personal and medical equipment.

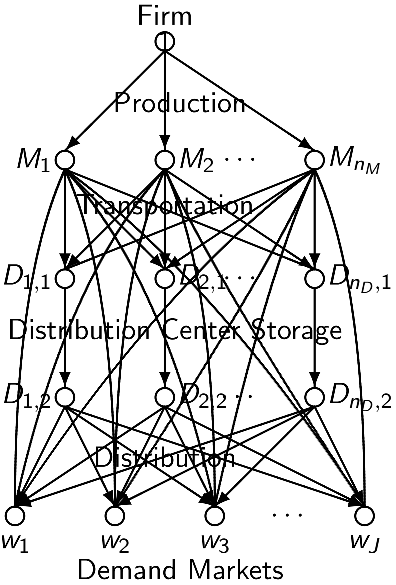


Figure: The Supply Chain Network Topology

Supply Chain Model with Different Labor Constraints

The model considers three sets of labor constraints, of increasing flexibility of movement.

1. **In the first set**, **each supply chain link has an upper bound of available labor.** Labor is is not free to move to other production sites, nor to other distribution centers, or assist in freight service provision.
2. **In the second set**, **labor is free to move across a supply chain set of network economic activities (such as production, or transportation, or storage, and, finally, distribution).** There is a capacity of labor associated with each such "tier" of supply chain links. Those who have skills in production, or in distribution, etc., may be reallocated. This has been happening in freight service provision, for example, during the Covid-19 pandemic.
3. **In the third set**, **labor is free to move across all the supply chain network economic activities, and there is a single capacity.** McKinsey & Company noted this is a means towards resilience and returning the supply chain to effectiveness while reenvisioning and reforming.

Supply Chain Model with Different Labor Constraints

Our findings include:

1. **Having appropriate healthcare pandemic mitigation processes and procedures in place is essential to continuing operations.** With even one of the two manufacturing plants closed, the can prices rise at the demand markets.

2. **Reduction in labor availability can result in a significant increase in product prices at the consumer level.**

3. **Even in the case of reduced labor availability, electronic commerce can result in increased profits.**

4. **Having the flexibility of labor being able to be reallocated across supply chain network activities can enable enhanced profits.**

Methodology - The VI Problem

Methodology - The Variational Inequality Problem

We utilize the theory of variational inequalities for the formulation, analysis, and solution of both centralized and decentralized supply chain network problems.

Definition: The Variational Inequality Problem

The finite-dimensional variational inequality problem, $\mathrm{VI}(F, \mathcal{K})$*, is to determine a vector* $X^* \in \mathcal{K}$*, such that:*

$$\langle F(X^*), X - X^* \rangle \geq 0, \quad \forall X \in \mathcal{K},$$

where F *is a given continuous function from* $\mathcal{K}$ *to* R^N*,* $\mathcal{K}$ *is a given closed convex set, and* $\langle \cdot, \cdot \rangle$ *denotes the inner product in* R^N*.*

The vector X consists of **the decision variables** – typically, the flows (products, prices, etc.).

$\mathcal{K}$ is the **feasible set representing how the decision variables are constrained** – for example, the flows may have to be nonnegative; budget constraints may have to be satisfied; similarly, quality and/or time constraints may have to be satisfied.

The function F that enters the variational inequality represents **functions that capture the behavior in the form of the functions such as costs, profits, risk, etc.**

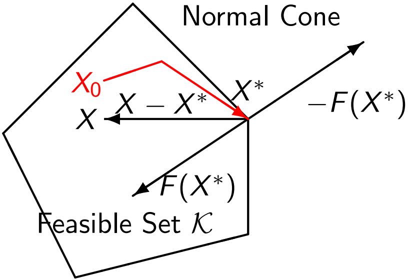
The variational inequality problem contains, as special cases, such mathematical programming problems as:

- systems of equations,
- optimization problems,
- complementarity problems,
- game theory problems, operating under Nash equilibrium,
- and is related to the fixed point problem.

Hence, it is a natural methodology for a spectrum of supply chain network problems from centralized to decentralized ones.

Geometric Interpretation of VI($F, \mathcal{K}$) and a Projected Dynamical System (Dupuis and Nagurney, Nagurney and Zhang)

In particular, $F(X^*)$ is "orthogonal" to the feasible set $\mathcal{K}$ at the point X^*.



Associated with a VI is a Projected Dynamical System, which provides the natural underlying dynamics.

To model the **dynamic behavior of complex networks**, including supply chains, we utilize *projected dynamical systems* (PDSs) advanced by Dupuis and Nagurney (1993) in *Annals of Operations Research* and by Nagurney and Zhang (1996) in our book *Projected Dynamical Systems and Variational Inequalities with Applications*.

Such nonclassical dynamical systems are now being used in:

evolutionary games (Sandholm (2005, 2011)),

ecological predator-prey networks (Nagurney and Nagurney (2011a, b)),

even **neuroscience** (Girard et al. (2008),

dynamic spectrum model for cognitive radio networks (Setoodeh, Haykin, and Moghadam (2012)),

Future Internet Architectures (Saberi, Nagurney, Wolf (2014); see also Nagurney et al. (2015), Marentes et al. (2016)).

Game Theory and Supply Chain Network Models with Labor

This part of the presentation is based on the paper, **"Supply Chain Game Theory Network Modeling Under Labor Constraints: Applications to the Covid-19 Pandemic,"** A. Nagurney, *European Journal of Operational Research* **293(3)** (2021), pp 880-891, in which a game theory model for supply chains with labor was constructed, under three different sets of constraints, building on our previous work.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Production, Manufacturing, Transportation and Logistics

Supply chain game theory network modeling under labor constraints: Applications to the Covid-19 pandemic

Anna Nagurney

Department of Operations and Information Management, Isenberg School of Management, University of Massachusetts, Amherst, MA 01003, USA

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ABSTRACT

The Covid-19 pandemic has brought attention to supply chain networks due to disruptions for many reasons, including that of labor shortages as a consequences of illnesses, death, risk mitigation, as well as travel restrictions. Many sectors of the economy from food to healthcare have been competing for workers, as a consequence. In this paper, we construct a supply chain game theory network framework that captures labor constraints under three different scenarios. The appropriate equilibrium constructs are defined, along with their variational inequality formulations. Computed solutions to numerical examples inspired by shortages of migrant labor to harvest fresh produce; specifically, blueberries, in the United States, reveal the impacts of a spectrum of disruptions to labor on the product flows and the profits of the firms in the supply chain network economy. This research adds to the literature in both economics and operations research.

1. Introduction

The Covid-19 pandemic, officially declared by the World Health Organization on March 11, 2020, has demonstrated dramatically the importance of the health of workers to the global economy (Organization, 2020). Product supply chains as varied as those for Personal Protective Equipment (PPEs) (Burki, 2020) and other medical supplies (Ranney, Griffieth, & Jha, 2020), toilet paper and cleaning supplies (Gao, 2020), meat (Corkery & Yaffe-Bellany, 2020) and fresh produce (Knight, 2020; Laborde, Martin, Swinnen, & Vos, 2020), and even blood (Nagurney, 2020a), have been disrupted for reasons including that of the reduction of labor availability because of illnesses and death of workers, along with workers' fear of contracting the disease. Some workers have not been able to travel for seasonal employment because of travel restrictions to mitigate the spread of the coronavirus that causes the Covid-19 disease, resulting in both economic and personal losses (IHS-Markit, 2020). According to Elflein (2020), as of August 14, 2020, Covid-19 had spread to six continents, with over 750,000 succumbing to the coronavirus that causes the Covid-19 disease. Just over 2 months after, as of October 27, 2020, there were 1,160,421 documented deaths globally due to Covid-19 (JHU-CSSE2020, 2020). The negative impact of this global healthcare and economic crisis has affected different tiers of supply chains and associated network economic activities of production, transportation, storage, and distribution.

Labor has emerged as an essential factor in the functioning of supply chains in the pandemic. Without farmers, food cannot be produced. Without workers to harvest, food may end up rotting in the fields or be discarded (see Associated Press, 2020); without freight service provision food cannot be delivered to food processors; without food processors food cannot be processed, resulting in additional waste (see Polansek & Huffstutter, 2020). Ultimately, freight service provision is also essential for deliveries to retail outlets for purchase by consumers or even for direct transport to consumers using, for example, electronic commerce. Freight service workers have also been impacted by Covid-19 (Parker, 2020). Employees at distribution centers have been felled by Covid-19 (Daniels, 2020), as well, and Covid-19 has further exacerbated worker shortages at a time of greater demand because of electronic commerce (see Hardwick, 2020). Shortages of labor in manufacturing facilities were an issue even earlier on in February 2020 in China, since that country was impacted first by the coronavirus, which was to have originated in Wuhan, with implications for global supply chains (see Bloomberg, 2020). Labor shortages arose due to illnesses, need for social distancing in facilities, as well as adherence to quarantines. Each link of a product supply chain requires labor, and, therefore, reduction in labor capacity can propagate through paths of a supply chain network, affecting product flows as well as prices (see, e.g., OECD, 2020). Furthermore, unhealthy workers cannot be fully productive.

E-mail address: nagurney@isenberg.umass.edu

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Two sets of constraints have labor being shared among the competing supply chain networks of firms/organizations, in which case the governing concept is that of a **Generalized Nash Equilibrium** (rather than a Nash Equilibrium).

The research adds to modeling methodology as well as applications.

Game Theory Supply Chain Network Model with Labor

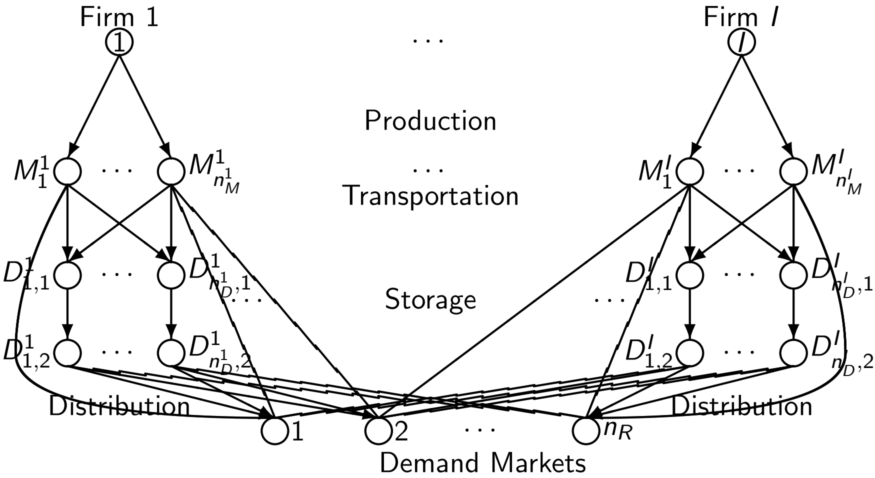


Figure: The Supply Chain Network Topology of the Game Theory Model with Labor

Table: Game Theory Supply Chain Network Model Notation

Notation	Definition
L^i	The set of links in firm i's supply chain network, with L being all the links.
$G = [N, L]$	the graph of the supply chain network consisting of all nodes N and all links L.
P_k^i	set of paths in firm i's supply chain network terminating in demand market k; $\forall i, k$.
P^i	set of all n_{P^i} paths of firm i; $i = 1, \ldots, I$.
P	set of all n_P paths in the supply chain network economy.
$x_p; p \in P_k^i$	nonnegative flow on path p originating at firm node i and terminating at k; $\forall i, k$. Group firm i's path flows into vector $x^i \in R_+^{n_{P^i}}$. Then group all firms' path flows into vector $x \in R_+^{n_P}$.
f_a	nonnegative flow of the product on link a, $\forall a \in L$. Group all link flows into vector $f \in R_+^{n_L}$.
l_a	labor on link a (usually denoted in person hours).
α_a	positive factor relating input of labor to output of product flow on link a, $\forall a \in L$.
$\bar{l}_a$	bound on the availability of labor on link a under Scenario 1, $\forall a \in L$
$\bar{l}^t$	bound on labor availability for tier t activities under Scenario 2. $T+1$ is electronic commerce tier.
$\bar{l}$	bound on labor availability under Scenario 3.
d_{ik}	demand for the product of firm i at demand market k; $\forall i, k$. Group $\{d_{ik}\}$ elements for firm i into vector $d^i \in R_+^{n_R}$ and all demands into vector $d \in R_+^{I \times n_R}$.
$\hat{c}_a(f)$	total operational cost associated with link a, $\forall a \in L$.
π_a	cost of a unit of labor on link a, $\forall a$.
$\rho_{ik}(d)$	demand price function for the product of firm i at demand market k; $\forall i, k$.

Game Theory Supply Chain Network Model with Labor

For each firm i; $i = 1, \ldots, I$, we must have that:

$$\sum_{p \in P_k^i} x_p = d_{ik}, \quad k = 1, \ldots, n_R. \tag{1}$$

The path flows must be nonnegative; that is, for each firm i; $i = 1, \ldots, I$:

$$x_p \geq 0, \quad \forall p \in P^i. \tag{2}$$

The link flows of each firm i; $i = 1, \ldots, I$, are related to the path flows as:

$$f_a = \sum_{p \in P} x_p \delta_{ap}, \quad \forall a \in L^i, \tag{3}$$

where $\delta_{ap} = 1$, if link a is contained in path p, and 0, otherwise.
We now discuss how labor is related to product flow.

$$f_a = \alpha_a l_a, \quad \forall a \in L^i, \quad i = 1, \ldots, I. \tag{4}$$

The utility function of firm i, U^i; $i = 1, \ldots, I$, is the profit, given by the difference between its revenue and its total costs:

$$U^i = \sum_{k=1}^{n_R} \rho_{ik}(d) d_{ik} - \sum_{a \in L^i} \hat{c}_a(f) - \sum_{a \in L^i} \pi_a l_a. \qquad (5a)$$

The functions U_i; $i = 1, \ldots, I$, are assumed to be concave, with the demand price functions being monotone decreasing and continuously differentiable and the total link cost functions being convex and also continuously differentiable.

The Optimization Problem of Each Firm

The optimization problem of each firm i; $i = 1, \ldots, I$, is:

$$\text{Maximize} \quad \sum_{k=1}^{n_R} \rho_{ik}(d) d_{ik} - \sum_{a \in L^i} \hat{c}_a(f) - \sum_{a \in L^i} \pi_a l_a, \qquad (5b)$$

subject to: (1), (2), (3), and (4).

Game Theory Supply Chain Network Model with Labor

Labor Scenario 1 – A Bound on Labor on Each Supply Chain Network Link

In Scenario 1, the additional constraints on the fundamental model are:

$$l_a \leq \bar{l}_a, \quad \forall a \in L. \tag{6}$$

Labor Scenario 2 – A Bound on Labor on Each Tier of Links in the Supply Chain Network

In Scenario 2, firms are faced with the ff. additional constraints:

$$\sum_{a \in L^1} l_a \leq \bar{l}^1, \qquad (7,1)$$

$$\sum_{a \in L^2} l_a \leq \bar{l}^2, \qquad (7,2)$$

and so on, until

$$\sum_{a \in L^{T+1}} l_a \leq l^{T+1}. \qquad (7, T+1)$$

Labor Scenario 3 – A Single Labor Bound on Labor for All the Links in the Supply Chain Network

Scenario 3 may be interpreted as being the least restrictive of the scenarios considered here in that labor can be transferable across different activities of production, transportation, storage, and distribution. In Scenario 3, in addition to constraints (1) through (4), the firms are now faced with the following single constraint:

$$\sum_{a \in L} l_a \leq \bar{l}. \tag{8}$$

Recall that x^i denotes the vector of strategies, which are the path flows, for each firm i; $i = 1, \ldots, I$. We can redefine the utility/profit functions $\tilde{U}^i(x) \equiv U^i$; $i = 1 \ldots, I$ and group the profits of all the firms into an I-dimensional vector $\tilde{U}$, such that

$$\tilde{U} = \tilde{U}(x). \tag{9}$$

Objective function (5b), in lieu of the above, can now be expressed as:

$$\text{Maximize } \tilde{U}^i(x) = \sum_{k=1}^{n_R} \tilde{\rho}_{ik}(x) \sum_{p \in P_k^i} x_p - \sum_{a \in L^i} \tilde{c}_a(x) - \sum_{a \in L^i} \frac{\pi_a}{\alpha_a} \sum_{p \in P} x_p \delta_{ap}. \tag{10}$$

Scenario 1 Nash Equilibrium Conditions

We define the feasible set K_i for firm i:

$K_i \equiv \{x^i | x^i \in R_+^{n_{P^i}}, \frac{\sum_{p \in P^i} x_p \delta_{ap}}{\alpha_a} \leq \bar{l}_a, \forall a \in L^i\}$, for $i = 1, \ldots, I$.

Also, we define $K \equiv \prod_{i=1}^{I} K_i$.

In Scenario 1, each firm competes noncooperatively until the following equilibrium is achieved.

Definition: Supply Chain Network Nash Equilibrium for Scenario 1

A path flow pattern $x^* \in K$ is a supply chain network Nash Equilibrium if for each firm i; $i = 1, \ldots, I$:

$$\tilde{U}^i(x^{i*}, \hat{x}^{i*}) \geq \tilde{U}^i(x^i, \hat{x}^{i*}), \quad \forall x^i \in K_i, \tag{11}$$

where $\hat{x}^{i*} \equiv (x^{1*}, \ldots, x^{i-1*}, x^{i+1*}, \ldots, x^{I*})$.

Variational Inequality Formulations

Applying the classical theory of Nash equilibria and variational inequalities, under our imposed assumptions on the underlying functions, it follows that (cf. Gabay and Moulin (1980) and Nagurney (1999)) the solution to the above Nash Equilibrium problem (see Nash (1950, 1951)) coincides with the solution of the variational inequality problem: determine $x^* \in K$, such that

$$-\sum_{i=1}^{I} \langle \nabla_{x^i} \tilde{U}^i(x^*), x^i - x^{i*} \rangle \geq 0, \quad \forall x \in K, \tag{12}$$

where $\langle \cdot, \cdot \rangle$ represents the inner product in the corresponding Euclidean space, which here is of dimension n_P, and $\nabla_{x^i} \tilde{U}^i(x)$ is the gradient of $\tilde{U}^i(x)$ with respect to x^i.

We introduce Lagrange multipliers λ_a associated with constraint (6), $\forall a \in L$ and group the Lagrange multipliers for each firm i's network L^i into the vector λ^i. Group all such vectors for firms into vector $\lambda \in R_+^{n_L}$. Define feasible sets: $K_i^1 \equiv \{(x^i, \lambda^i) | (x^i, \lambda^i) \in R_+^{n_{P^i} + n_{L^i}}\}$; $i = 1, \ldots, I$, and $K^1 \equiv \prod_{i=1}^{I} K_i^1$.

Variational Inequality Formulations

Theorem: Alternative VI of Nash Equilibrium for Scenario 1

The supply chain network Nash Equilibrium satisfying the Definition 3.1 is equivalent to the solution of the variational inequality: determine vectors of path flows and Lagrange multipliers, $(x^*, \lambda^*) \in K^1$, where:

$$\sum_{i=1}^{m}\sum_{k=1}^{n_R}\sum_{p\in P_k^i}\left[\frac{\partial \tilde{C}_p(x^*)}{\partial x_p}+\sum_{a\in L^i}\frac{\lambda_a^*}{\alpha_a}\delta_{ap}+\sum_{a\in L^i}\frac{\pi_a}{\alpha_a}\delta_{ap}-\tilde{\rho}_{ik}(x^*)-\sum_{l=1}^{n_R}\frac{\partial \tilde{\rho}_{il}(x^*)}{\partial x_p}\sum_{q\in P_l^i}x_q^*\right]\times[x_p-x_p^*]$$

$$+\sum_{a\in L}\left[\bar{l}_a-\frac{\sum_{p\in P}x_p^*\delta_{ap}}{\alpha_a}\right]\times[\lambda_a-\lambda_a^*]\geq 0,\quad \forall (x,\lambda)\in K^1; \tag{13}$$

where for each path p; $p \in P_k^i$; $i = 1, \ldots, m$; $k = 1, \ldots, n_R$:

$$\frac{\partial \tilde{C}_p(x)}{\partial x_p}\equiv\sum_{a\in L^i}\sum_{b\in L^i}\frac{\partial \hat{c}_b(f)}{\partial f_a}\delta_{ap}, \tag{14}$$

$$\frac{\partial \tilde{\rho}_{ik}(x)}{\partial x_p}\equiv\frac{\partial \rho_{il}(d)}{\partial d_{ik}}. \tag{15}$$

For both Scenarios 2 and 3, we use a refinement of the Generalized Nash Equilibrium, known as a *Variational Equilibrium* to construct variational inequality formulations.

Hence, the labor supply chain network equilibrium models, under three different scenarios of constraints, can be uniformly qualitatively studied and solution to numerical problems, quantitatively computed using rigorous algorithms!

All the variational inequalities can be put into standard form; VI$(F, \mathcal{K})$, where one seeks to determine a vector $X^* \in \mathcal{K} \subset R^N$, such that

$$\langle F(X^*), X - X^* \rangle \geq 0, \quad \forall X \in \mathcal{K}, \tag{16}$$

where F is a given continuous function from $\mathcal{K}$ to R^N, $\mathcal{K}$ is a given closed, convex set, and $\langle \cdot, \cdot \rangle$ denotes the inner product in N-dimensional Euclidean space.

The Modified Projection Method

Step 0: Initialization

Initialize with $X^0 \in \mathcal{K}$. Set the iteration counter $\tau := 1$ and let β be a scalar such that $0 < \beta \leq \frac{1}{L}$, where L is the Lipschitz constant.

Step 1: Computation

Compute $\bar{X}^\tau$ by solving the variational inequality subproblem:

$$\langle \bar{X}^\tau + \beta F(X^{\tau-1}) - X^{\tau-1}, X - \bar{X}^\tau \rangle \geq 0, \quad \forall X \in \mathcal{K}. \tag{17}$$

Step 2: Adaptation

Compute X^τ by solving the variational inequality subproblem:

$$\langle X^\tau + \beta F(\bar{X}^\tau) - X^{\tau-1}, X - X^\tau \rangle \geq 0, \quad \forall X \in \mathcal{K}. \tag{18}$$

Step 3: Convergence Verification

If $|X^\tau - X^{\tau-1}| \leq \epsilon$, with $\epsilon > 0$, a pre-specified tolerance, then stop; otherwise, set $\tau := \tau + 1$ and go to Step 1.

Realization of the Modified Projection Method Computation Step for VI (13)

Specifically, at iteration τ, we compute each of the path flows $\bar{x}_p^\tau$, $\forall P_k^i$, $\forall i$, $\forall k$, according to:

$$\bar{x}_p^\tau = \max\{0, x_p^{\tau-1} - \beta(\frac{\partial \tilde{C}_p(x^{\tau-1})}{\partial x_p} + \sum_{a\in L^i} \frac{\lambda_a^{\tau-1}}{\alpha_a}\delta_{ap} + \sum_{a\in L^i} \frac{\pi_a}{\alpha_a}\delta_{ap}$$

$$-\tilde{\rho}_{ik}(x^{\tau-1}) - \sum_{l=1}^{n_R} \frac{\partial \tilde{\rho}_{il}(x^{\tau-1})}{\partial x_p} \sum_{q\in P_l^i} x_q^{\tau-1})\} \quad (19)$$

and each of the Lagrange multipliers $\bar{\lambda}_a^\tau$, $\forall a \in L$, according to:

$$\bar{\lambda}_a^\tau = \max\{0, \lambda_a^{\tau-1} - \beta(\bar{l}_a - \frac{\sum_{p\in P} x_p^{\tau-1}\delta_{ap}}{\alpha_a})\}. \quad (20)$$

Realization of the Modified Projection Method Adaptation Step for VI (13)

At iteration τ, we compute each of the path flows x_p^τ, $\forall P_k^i$, $\forall i$, $\forall k$, according to:

$$x_p^\tau = \max\{0, x_p^{\tau-1} - \beta(\frac{\partial \tilde{C}_p(\bar{x}^\tau)}{\partial x_p} + \sum_{a\in L^i} \frac{\bar{\lambda}_a^\tau}{\alpha_a}\delta_{ap} + \sum_{a\in L^i} \frac{\pi_a}{\alpha_a}\delta_{ap} - \tilde{\rho}_{ik}(\bar{x}^\tau)$$

$$- \sum_{l=1}^{n_R} \frac{\partial \tilde{\rho}_{il}(\bar{x}^\tau)}{\partial x_p} \sum_{q\in P_l^i} \bar{x}_q^\tau)\} \tag{21}$$

and each of the Lagrange multipliers λ_a^τ, $\forall a \in L$, according to:

$$\lambda_a^\tau = \max\{0, \lambda_a^{\tau-1} - \beta(\bar{l}_a - \frac{\sum_{p\in P} \bar{x}_p^\tau \delta_{ap}}{\alpha_a})\}. \tag{22}$$

Our numerical examples are based on disruptions in migrant labor in the blueberry supply chain in the Northeast of the US in the summer of 2020.

The numerical examples investigate:

• Modifications in demand price functions;
• Disruptions in labor on a supply chain network link,
with additional numerical examples presented in the EJOR paper.

Examples 1, 2, and 3 have the supply chain network topology given below. There are two competing food firms (blueberry farms), each with two production locations, and with a single distribution center. There are two demand markets. We consider Scenario 1.

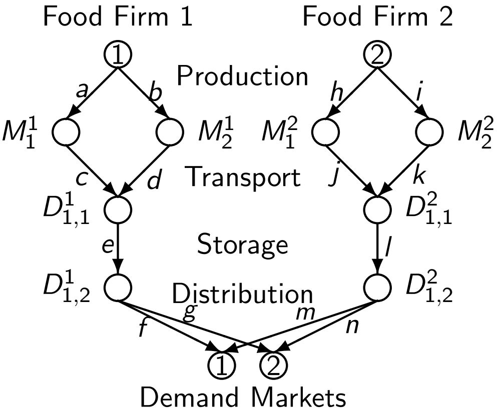


Figure: The Supply Chain Network Topology for the Numerical Examples

Example 1 - Baseline Example

The total operational cost functions for Food Firm 1 on its supply chain network L^1 are:

$$\hat{c}_a(f) = .0006f_a^2, \quad \hat{c}_b(f) = .0007f_b^2, \quad \hat{c}_c(f) = .001f_c^2, \quad \hat{c}_d(f) = .001f_d^2,$$

$$\hat{c}_e(f) = .002f_e^2, \quad \hat{c}_f(f) = .005f_f^2, \quad \hat{c}_g(f) = .005f_g^2.$$

Also, the total operational costs associated with Food Firm 2's supply chain network L^2 are:

$$\hat{c}_h(f) = .00075f_h^2, \quad \hat{c}_i(f) = .0008f_i^2, \quad \hat{c}_j(f) = .0005f_j^2, \quad \hat{c}_k(f) = .0005f_k^2,$$

$$\hat{c}_l(f) = .0015f_l^2, \quad \hat{c}_m(f) = .01f_m^2, \quad \hat{c}_n(f) = .01f_n^2.$$

The costs for labor (wages) for Food Firm 1 are:

$$\pi_a = 10, \quad \pi_b = 10, \quad \pi_c = 15, \quad \pi_d = 15, \quad \pi_e = 20, \quad \pi_f = 17, \quad \pi_g = 18,$$

and for Food Firm 2:

$$\pi_h = 11, \quad \pi_i = 22, \quad \pi_j = 15, \quad \pi_k = 15, \quad \pi_l = 18, \quad \pi_m = 18, \quad \pi_n = 18.$$

Example 1 - Baseline Example

The link labor productivity factors for the first firm are:

$$\alpha_a = 24,\ \alpha_b = 25,\ \alpha_c = 100,\ \alpha_d = 100,\ \alpha_e = 50,\ \alpha_f = 100,\ \alpha_g = 100,$$

and for the second firm:

$$\alpha_h = 23,\ \alpha_i = 24,\ \alpha_j = 100,\ \alpha_k = 100,\ \alpha_l = 70,\ \alpha_m = 100,\ \alpha_n = 100.$$

The bounds on labor for the first firm are:

$$\bar{l}_a = 10, \quad \bar{l}_b = 200, \quad \bar{l}_c = 300, \quad \bar{l}_d = 300, \quad \bar{l}_e = 100, \quad \bar{l}_f = 120, \quad \bar{l}_g = 120,$$

and for the second firm:

$$\bar{l}_h = 800, \quad \bar{l}_i = 90, \quad \bar{l}_j = 200, \quad \bar{l}_k = 200, \quad \bar{l}_l = 300, \quad \bar{l}_m = 100, \quad \bar{l}_n = 100.$$

Observe that the labor availability on link a is low. This is done in order to capture a disruption to labor in the pandemic.

The demand price functions for Food Firm 1 are:

$$\rho_{11}(d) = -.0001d_{11} - .00005d_{21} + 6, \quad \rho_{12}(d) = -.0002d_{12} - .0001d_{22} + 8.$$

The demand price functions for Food Firm 2 are:

$$\rho_{21}(d) = -.0003d_{21} + 7, \quad \rho_{22}(d) = -.0002d_{22} + 7.$$

The paths are: $p_1 = (a, c, e, f)$, $p_2 = (b, d, e, f)$, $p_3 = (a, c, e, g)$, path $p_4 = (b, d, e, g)$, $p_5 = (h, j, l, m)$, $p_6 = (i, k, l, m)$, $p_7 = (h, j, l, n)$, and $p_8 = (i, k, l, n)$.

All the Lagrange multipliers are equal to 0.00 except for $\lambda_a^* = 4.925$ with the labor equilibrium value on link a equal to its upper bound of 10.00.

The product prices at equilibrium are:

$$\rho_{11} = 5.97, \quad \rho_{12} = 7.91, \quad \rho_{21} = 6.94, \quad \rho_{22} = 6.96,$$

with equilibrium demands of:

$$d_{11}^* = 172.07, \quad d_{12}^* = 359.15, \quad \rho_{21} = 195.94, \quad \rho_{22} = 197.86.$$

The profit of Food Firm 1 is: 1,671.80 and the profit of Food Firm 2 is: 1,145.06.

Example 2 – Modification of Demand Price Functions

Example 2 has the same data as Example 1 except that we modify the demand price functions for the second firm to include a cross term, so that:

$$\rho_{21}(d) = -.0003 d_{21} - .0001 d_{11} + 6, \quad \rho_{22}(d) = -.0002 d_{22} - .0001 d_{12} + 7.$$

The Lagrange multipliers are all equal to 0.00 except for $\lambda_a^* = 4.93$.

Example 2 – Modification of Demand Price Functions

The product prices at equilibrium are now:

$$\rho_{11} = 5.97, \quad \rho_{12} = 7.91, \quad \rho_{21} = 6.92, \quad \rho_{22} = 6.92,$$

with the equilibrium demands:

$$d_{11}^* = 172.07, \quad d_{12}^* = 359.16, \quad d_{21}^* = 195.48, \quad d_{22}^* = 196.48.$$

The profit for Food Firm 1 is: 1,671.86 and the profit for Food Firm 2 is: 1,134.61. The profit for Food Firm 1 rises ever so slightly, whereas that for Food Firm 2 decreases.

Example 3 has the same data as Example 2 except that we now consider a sizable disruption in terms of the spread of COVID-19 at the distribution centers of both food firms with the bounds on labor corresponding to the associated respective links being reduced to:

$$\bar{l}_e = 5, \quad \bar{l}_l = 5.$$

All computed equilibrium Lagrange multipliers are now equal to 0 except for those associated with the distribution center links, since the equilibrium labor values attain the imposed upper bounds on links e and l, with the respective equilibrium Lagrange multiplier values being:

$$\lambda_e^* = 157.2138, \quad \lambda_l^* = 43.6537.$$

Example 3 – Disruptions of Labor in Storage Facilities

The product prices at equilibrium are now:

$$\rho_{11} = 5.99, \quad \rho_{12} = 7.94, \quad \rho_{21} = 6.94, \quad \rho_{22} = 6.94,$$

with the equilibrium demands:

$$d^*_{11} = 30.03, \quad d^*_{12} = 219.96, \quad d^*_{21} = 174.61, \quad d^*_{22} = 175.39.$$

The profit for Food Firm 1 is now dramatically reduced to 1,218.74 and the profit for Food Firm 2 also declines, but by a much smaller amount, to 1,126.73.

Equilibrium Path Flows

Table: Equilibrium Product Path Flows for Examples 1 Through 3

Equilibrium Product Path Flows	Ex. 1	Ex. 2	Ex. 3
$x_{p_1}^*$	73.23	73.22	15.65
$x_{p_2}^*$	98.85	98.85	14.38
$x_{p_3}^*$	166.77	166.78	110.60
$x_{p_4}^*$	192.38	192.38	109.35
$x_{p_5}^*$	142.85	142.62	131.97
$x_{p_6}^*$	53.08	52.86	42.63
$x_{p_7}^*$	143.81	143.12	132.36
$x_{p_8}^*$	54.04	53.36	43.02

Table: Equilibrium Link Labor Values for Examples 1 Through 3

Equilibrium Link Labor Values	**Ex. 1**	**Ex. 2**	**Ex. 3**
l_a^*	10.00	10.00	5.26
l_b^*	11.65	11.65	4.95
l_c^*	2.40	2.40	1.26
l_d^*	2.91	2.91	1.24
l_e^*	10.62	10.62	5.00
l_f^*	1.72	1.72	0.30
l_g^*	3.59	3.59	2.20
l_h^*	12.46	12.42	11.49
l_i^*	4.46	4.43	3.57
l_j^*	2.87	2.86	2.64
l_k^*	1.07	1.06	0.86
l_l^*	5.63	5.60	5.00
l_m^*	1.96	1.95	1.75
l_n^*	1.98	1.96	1.75

Farmers should do everything possible to secure the health of workers at their production/harvesting and other facilities, so that the blueberries can be harvested in a timely manner and so that profits do not suffer. Keeping workers healthy, through appropriate measures, impacts the bottom line!

Some Additional Research

A. Nagurney, "Attracting International Migrant Labor: Investment Optimization to Alleviate Supply Chain Labor Shortages," *Operations Research Perspectives* **9 (2022), 100233.**

A. Nagurney, "Optimization of Investments in Labor Productivity in Supply Chain Networks," *International Transactions in Operational Research* **29(4), (2022), pp 2116-2144. This article was recognized with an Editor's Choice Award.**

A. Nagurney, "Supply Chain Networks, Wages, and Labor Productivity: Insights from Lagrange Analysis and Computations," *Journal of Global Optimization* **83 (2022), pp 615-638.**

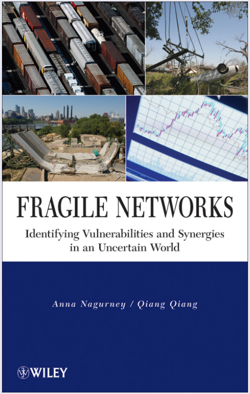
Some Additional Research

The numerical results in our papers clearly reveal the importance of a holistic approach to supply chain network modeling since decisions made by a specific firm can have unexpected impacts on other competing firms in the supply chain network economy.

Our results also strongly suggest that having wages and labor equilibrate without any wage ceilings can be beneficial for an individual firm and also for firms engaged in competition.

And, most importantly, taking care of workers is critical in times of peace and war!

Resilience of Supply Chain Networks



How to quantify the resilience of a supply chain network in general and, specifically, with respect to disruptions in labor availability and productivity.


Resilience Findings
June 16, 2022 AEST
Resilience of Supply Chain Networks to Labor Disruptions
Anna Nagurney, Ph.D., Alireza Ermagun, Ph.D.

Efficiency/Performance of a Supply Chain Network

The efficiency/performance of a defense supply chain network, denoted by *efficiency*, $\mathcal{E}$, is defined as:

$$\mathcal{E} = \mathcal{E}(G, \hat{c}, \rho, \pi, \alpha, \bar{l}) \equiv \sum_{i=1}^{I} \sum_{k=1}^{n_R} \frac{\frac{d^*_{ik}}{\rho_{ik}(d^*)}}{In_R}, \tag{23}$$

with the demands, d^*, and the incurred demand market prices in (23), evaluated at the solution to the VI problem.

Given a supply chain network economy, and the various parameters and functions, the corresponding multi-firm supply chain network is considered as performing better if, on the average, it can handle higher demands at lower prices.

Importance of a Supply Chain Network Component

Following then Nagurney and Qiang (2009), one can then define the importance of a component g (node, link, or a combination of nodes and links), $I(g)$, which represents the efficiency drop when g is removed from the defense supply chain network, as:

$$I(g) = \frac{\Delta \mathcal{E}}{\mathcal{E}} = \frac{\mathcal{E}(G, \hat{c}, \rho, \pi, \alpha, \bar{l}) - \mathcal{E}(G - g, \hat{c}, \rho, \pi, \alpha, \bar{l})}{\mathcal{E}(G, \hat{c}, \rho, \pi, \alpha, \bar{l})}. \quad (24)$$

One can then rank the importance of nodes or links using (24).

I adapt the measure proposed in Nagurney and Ermagun (2022) for the supply chain network game theory model. As therein, let $\bar{l}\gamma$ denote the reduction of labor availability with $\gamma \in (0,1]$ so if $\gamma = .8$ this means that the labor availability associated with the labor constraints is now 80% of the original labor availability as in $\mathcal{E}$.

Resilience Measure Capturing Labor Availability

One can define the resilience measure with respect to labor availability, $\mathcal{R}^{\bar{l}\gamma}$, as

$$\mathcal{R}^{\bar{l}\gamma} \equiv \mathcal{R}^{\bar{l}\gamma}(G, \hat{c}, \rho, \pi, \alpha, \bar{l}) = \frac{\mathcal{E}^{\bar{l}\gamma}}{\mathcal{E}} \times 100\%, \tag{25}$$

with $\mathcal{E}$ as in (22).

The closer the value is to 100%, the greater the resilience.

I constructed a similar resilience measure for labor productivity.

Solving multiple distinct supply chain network examples, we find:

(1). a **free movement of labor across the supply chain network results in a higher efficiency of the supply chain as well as a higher resilience**;

(2). a **reduction in labor productivity can impact the supply chain network efficiency and the corresponding resilience**, and

(3). the **presence of electronic commerce escalates the efficiency of the supply chain network** but **diminishes resilience**.

Dealing with the Media and Impacting Policy

Writing OpEds

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How disaster relief efforts could be improved with game theory

March 9, 2017 11.21pm EST

Buddhist monks and family members of victims of the Fukushima tsunami and earthquake face the sea to pray on March 11, 2016 while mourning the victims of the March 11, 2011 disaster. REUTERS/Kyodo

Author
Anna Nagurney
John F. Smith Memorial Professor of Operations Management, University of Massachusetts Amherst

Disclosure statement
Anna Nagurney does not work for, consult, own shares in or receive funding from any company or organization that would benefit from this article, and has disclosed no relevant affiliations beyond the academic appointment above.

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The number of disasters has doubled globally since the 1980s, with the

Chicago Tribune

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Response to natural disasters like Harvey could be helped with game theory

By Anna Nagurney
Associated Press

AUGUST 29, 2017 | BOSTON, MASSACHUSETTS

(The Conversation is an independent and nonprofit source of news, analysis and commentary from academic experts.)

Anna Nagurney, University of Massachusetts Amherst

(THE CONVERSATION) The devastation by Hurricane Harvey continues, with the National Weather Service calling the event unprecedented, thus making the response even more complicated.

Nearly half a million people are expected to seek federal aid in the aftermath of the Category 4 hurricane, which already has dumped more than 30 inches on the Houston

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THURSDAY, AUG 31, 2017 10:38 AM EST

Time for some game theory: How responses to natural disasters like Harvey could be improved

The damage and losses from natural disasters are estimated to cost us $100 billion a year since 2000

ANNA NAGURNEY, THE CONVERSATION

Homeland Security News Wire

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Disaster response

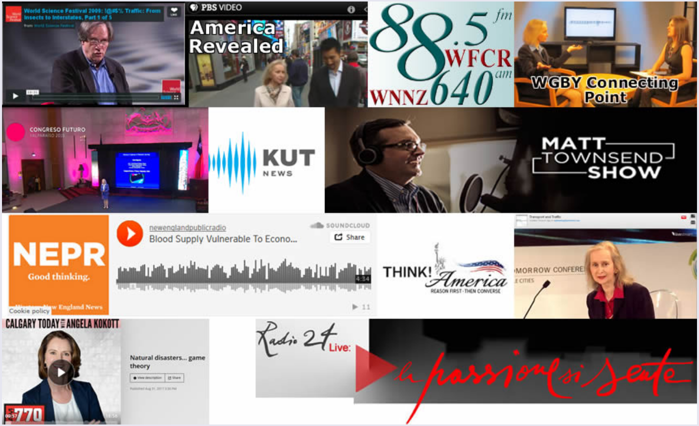
How disaster relief efforts could be improved with game theory

By Anna Nagurney

Published 13 March 2017 | Share

The number of disasters has doubled globally since the 1980s, with the damage and losses estimated at an average

Coverage by the Media



On March 11, 2020 the WHO declared the pandemic. On March 12 my article on blood supply chains in *The Conversation* appeared and, on March 24 my article in INFORMS *Analytics Coronavirus Chronicles*.

THE CONVERSATION
Academic rigor, journalistic flair

How coronavirus is upsetting the blood supply chain

March 12, 2020 8.05am EDT

Email
Twitter 28
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The coronavirus, which causes the disease COVID-19, has created enormous anxiety, uncertainty, and disruption to our lives. Much has already been written about potential shortages of medicines and face masks, but little has been said about something only you and I can provide – lifesaving blood.

Our nation's blood supply is essential to our health care security. Blood transfusions are integral parts of major surgeries. Blood is used in the treatment of diseases, particularly sickle cell anemia and some cancers. Blood is needed for victims who have injuries caused by accidents or natural disasters. Every day, the U.S. needs 36,000 units of red blood cells, 7,000 units of platelets, and 10,000 units of plasma.

I am a professor and director of the Virtual Center for Supernetworks at the University of Massachusetts Amherst. Because of the escalating coronavirus health care crisis, I am deeply concerned the U.S. blood supply chain is under stress. The timing could hardly be worse; the COVID-19 outbreak coincides with our seasonal flus and colds.

Patients need blood in many states

Many states, including Washington, California, Kansas, Pennsylvania, the Carolinas, Massachusetts and Rhode Island, are now calling for blood donations. At the same time, some states are closing schools and other sites that typically host mobile blood drives; even prior to the coronavirus, some events had been canceled. In Massachusetts, the Red Cross announced last September it would no

Analytics
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March 24, 2020 in Coronavirus Chronicles

The COVID-19 Pandemic and the Stressed Blood Supply Chain

By Anna Nagurney

SHARE: PRINT ARTICLE: https://doi.org/10.1287/LYTX.2020.02.18

Blood is essential to our nation's healthcare security. It is a life-saving product that cannot be manufactured and comes solely from volunteer donors. No substitute for blood has yet been invented. Blood transfusions are integral parts of major surgeries. Blood is a must for saving victims of accidents and natural disasters. Blood is also used in the treatment of certain diseases, including certain cancers. In the United States, 36,000 units of red blood cells are needed daily as are 7,000 units of platelets and 10,000 units of plasma. A typical donation of one pint, which can be divided into red blood cells, plasma and platelets, can save up to three lives. Adults have 8-12 pints of blood.

Even in the best of times, the complex blood supply chain in the United States is under stress. Although 38% of the U.S. population is eligible to donate blood, less than 10% actually does so in a year. Furthermore, issues of seasonality come into play with flu and colds cutting donations; the same for weather-related events and holidays. To further complicate matters, blood is perishable; platelets last five days and red blood cells have a shelf life of 42 days.

The blood banking industry, entrusted with maintaining a sufficient supply of blood, is facing a battle of the century with the COVID-19 pandemic. The timing could not be worse with this year's heavy flu and cold season, and the blood banking industry having recently undergone a massive transformation due to both economics and changes in medical procedures [1]. For example, there is increased competition among blood service organizations for donors [2]. The American Red Cross has closed some testing facilities and even eliminated mobile collection units in parts of the country. There have also been mergers and acquisitions of blood service organizations [3]. On the other hand, hospitals are now requiring less blood for certain procedures as compared to a few years ago because of changes in medical practices. This has resulted in requests for lower prices for blood from blood banks, who still have to cover costs, and some of the new costs include higher testing costs due to diseases such as Zika. And now, because of the COVID-19 pandemic, a major source of blood donations – schools – is removed.

The critical blood supply chain is unique from others that we study in operations research (O.R.) because it requires altruistic donations, collection, testing, processing and distribution to hospitals and medical centers. The blood supply chain can be visualized, modeled and studied as a network [4]. The coronavirus can disrupt the links in the blood supply chain network through a variety of means. If donors are ill, they cannot donate; if the staff is ill, they cannot collect, test, process and distribute blood. If our healthcare workers are compromised, they cannot transfuse.

In China, specifically Wuhan where the coronavirus is generally thought to have originated, blood donations have

Writing OpEds in the Pandemic

On August 4, 2020, I published an article in *The Conversation*,

"The Raging Competition for Medical Supplies is not a Game, but Game Theory Can Help."

On September 18, 2020, I published another article in *The Conversation*,

"Keeping Coronavirus Vaccines at Subzero Temperatures During Distribution Will Be Hard, but Likely Key to Ending Pandemic."

Writing OpEds in the Pandemic

On January 8, 2021, my article,

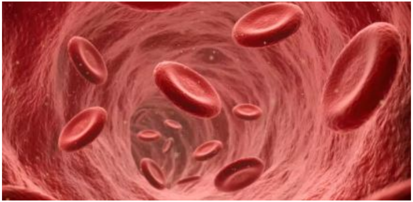
"Vaccine Delays Reveal Unexpected Weak Link in Supply Chains: A Shortage of Workers," appeared in *The Conversation*.

On April 5, 2021, I published the article,

"Today's Global Economy Runs on Standardized Containers, as the Ever Given Fiasco Illustrates," also in *The Conversation*.

On September 21, 2021, my article,

"Global Shortage of Shipping Containers Highlights Their Importance in Getting Goods to Amazon Warehouses, Store Shelves and Your Door in Time for Christmas," appeared in *The Conversation*. It has had over 330,000 reads.



On February 3, 2022, my article,

"Heading into the Third Year of the Pandemic, the US Blood Supply is at a 10-Year Low," was published in *The Conversation*.

Some of My Media Interviews in the Pandemic

Some of the Media Interviews on the War on Ukraine

Economic dangers from Russia's invasion ripple across globe

By PAUL WISEMAN and DAVID McHUGH March 2, 2022

Feedstuffs went live.
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'I fear a cultural genocide'; Ukrainians in Western Mass. watch, worry and help

Published: Feb. 28, 2022, 5:55 p.m.

Threat of Russian cyber attacks likely for not just Ukraine, but also in the US

No Ikea Shelves, No Levis: The Retail Exodus From Russia Is On

Since the invasion of Ukraine began, the increasing financial and reputational risks of doing business in Russia are leading Western brands to halt operations.

Russian Sanctions Snarl Shipping Even as Pandemic Pressure Eases

March 11, 2022
Liz Alderman and Jenny Gross

Russian war in world's 'breadbasket' threatens food supply

By JOSEPH WILSON, SAMY MAGDY, AYA BATRAWY and CHINEDU ASADU March 6, 2022

Impacting Policy

On April 22, 2020, a letter from California Attorney General Xavier Becerra to the Admiral Brett Giroir, the Assistant Secretary of the US Department of Health & Human Services, and signed by US Attorney Generals of 21 other states, requested updates, because of the pandemic blood shortages, to blood donation policies that discriminate.

My March 2020 article in *The Conversation*, **which was reprinted in LiveScience, was the first reference and was cited on the first page.**

Impacting Policy

State of California
Office of the Attorney General
XAVIER BECERRA
ATTORNEY GENERAL

April 22, 2020

Via Electronic Mail

The Honorable Admiral Brett Giroir, MD
Assistant Secretary for Health
U.S. Department of Health & Human Services
Mary E. Switzer Building
330 C Street SW, Room L600
Washington, DC 20024
Attn: ACBTSA-PAHPAIA Sec. 209
ACBTSA@hhs.gov

RE: "Solicitation for Public Comments on Section 209 of the Pandemic and All-Hazards Preparedness and Advancing Innovation Act," 85 Fed. Reg. 16,372 (March 23, 2020)

Dear Assistant Secretary Giroir:

The undersigned State Attorneys General from California, Colorado, Connecticut, Delaware, the District of Columbia, Hawaii, Illinois, Iowa, Maine, Massachusetts, Michigan, Minnesota, Nevada, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Vermont, and Virginia submit this letter in response to the federal government's "Solicitation for Public Comments on Section 209 of the Pandemic and All-Hazards Preparedness and Advancing Innovation Act," (85 Fed. Reg. 16,372). We support the Office of the Assistant Secretary for Health in the U.S. Department of Health and Human Services' (HHS) efforts and work in maintaining an adequate national blood supply during the COVID-19 pandemic.

An adequate blood supply is critical to the nation's healthcare. Blood transfusions and blood products are needed for major surgeries, to treat diseases such as sickle cell anemia and some cancers, and to treat victims who have injuries caused by accidents or natural disasters.[1] Every day, the United States needs approximately 36,000 units of red blood cells, nearly 7,000

[1] Anna Nagurney, How Coronavirus is Upsetting the Blood Supply Chain, Live Science (Mar. 13, 2020), https://www.livescience.com/coronavirus-blood-supply-chain.html/.

1300 I STREET • SUITE 1740 • SACRAMENTO, CALIFORNIA 95814 • (916) 210-6029

Impacting Policy


Hon. Brett Giroir
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WILLIAM TONG
Connecticut Attorney General

KATHLEEN JENNINGS
Delaware Attorney General

KARL A. RACINE
District of Columbia Attorney General

CLARE E. CONNORS
Hawaii Attorney General

KWAME RAOUL
Illinois Attorney General

TOM MILLER
Iowa Attorney General

AARON M. FREY
Maine Attorney General

MAURA HEALEY
Massachusetts Attorney General

DANA NESSEL
Michigan Attorney General

KEITH ELLISON
Minnesota Attorney General

AARON D. FORD
Nevada Attorney General

GURBIR S. GREWAL
New Jersey Attorney General

HECTOR BALDERAS
New Mexico Attorney General

LETITIA JAMES
New York Attorney General

Xavier Becerra, previously California's Attorney General, has now been confirmed as President Joe Biden's Health and Human Services Secretary!

It's All About People!

Grazie Mille!

More information on our work can be found on the Supernetwork Center site:
https://supernet.isenberg.umass.edu/