NetwORks and Policies: OR to the Rescue

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Blackett Lecture, The Operational Research Society
The Royal Society, London, UK, December 5, 2024

Acknowledgments

I am deeply honored and very grateful for the opportunity to present to you today.

Many thanks also to The Royal Society for the beautiful venue.

Special acknowledgments and thanks to my collaborators and students who have made research and teaching always stimulating and rewarding.

Outline

- Background and Inspiration
- Network Systems and the Braess Paradox
- Representation of Supply Chains as Networks
- Food Supply Chains and Disruptions
- Cybercrime and Cybersecurity
- International Trade and Challenges
- Making a Positive Impact

Background and Inspiration

The Role of Great Britain and Lord Patrick Blackett

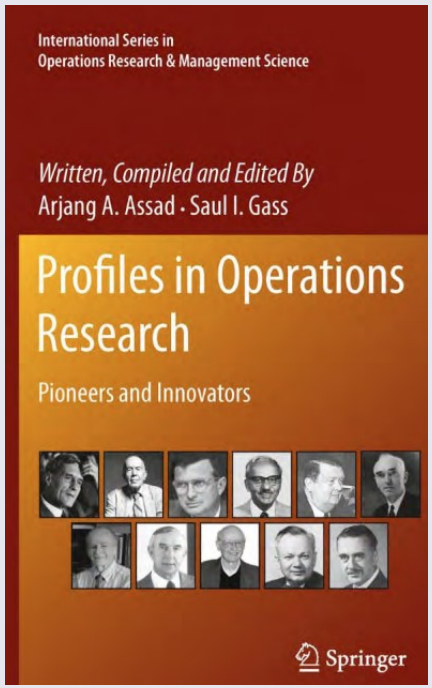
Operational Research (OR) was originally used in Britain during World War II to connote scientific research done to integrate new radar technologies into Royal Air Force tactics.

Lord Patrick Blackett is considered to be the Father of OR and served as the Director of Naval Operational Research at the Admiralty from 1942 to 1945. He was awarded the Nobel Prize in physics in 1948.

Blackett led a group that brought about significant improvement in the use of airborne radar for finding German submarines.

The Role of Great Britain and Lord Patrick Blackett

According to the book by Assad and Gass (2011), Blackett used his status as an outstanding physicist and Nobel Prize winner actively to promote "the scientist's responsibility to society and the public's need to understand scientific or technical evidence supporting or calling into question public policies."



Blackett epitomized "the twentieth century scientist as public citizen."

The Role of Great Britain

• **Lord Patrick Blackett was one of the four founders of the OR Club in 1948, which in 1953 became the Operational Research (OR) Society.**

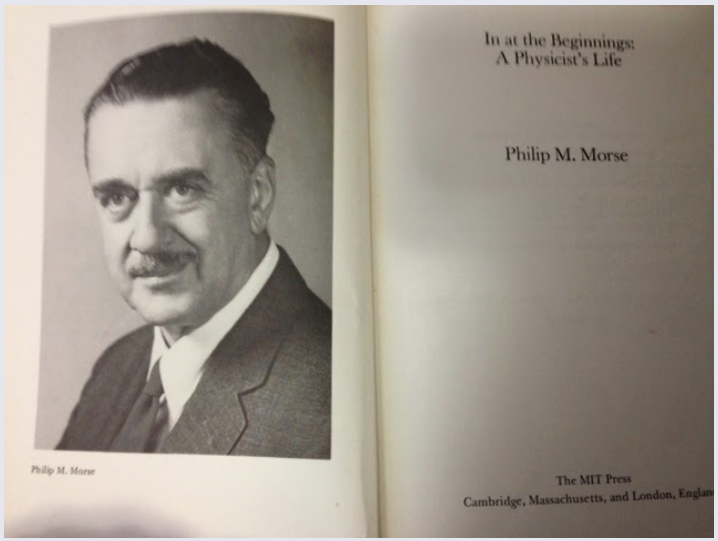
• **The first OR journal** - *Operational Research Quarterly* in 1950, which in 1978 became the *Journal of the Operational Research Society*.

• **OR1** conference takes place in 1958 in Harrogate.

• **The first dedicated Chair in OR** was established at Lancaster University in 1964, the same year as its founding.

Additional Acknowledgments

I would be remiss in also not acknowledging Philip M. Morse of MIT and George Dantzig of Stanford University on the other side of the Atlantic!



A Few Quotes

Philip M. Morse in his 1977 book, "In at the Beginnings" on page 318 writes:

The delights of research in O/R (he used the slash) are multiple. To me the pleasure coming from understanding how traffic behaves is as great as that coming from understanding how two atoms combine. In addition, the practical applications of O/R theory are often immediate and satisfying.

Morse ends his book with the following:

For those who like exploration, immersion in scientific research is not unsocial, is not dehumanizing; in fact, it is a lot of fun. And, in the end, if one is willing to grasp the opportunities, it can enable one to contribute something to human welfare.

OR - Our Profession

The founders of OR would be pleased to the see the growth of our discipline and profession with the discovery of and wide use of novel methodologies and innovative applications that they could not have envisioned in: **industry, government, defense, healthcare, high tech, consultancies, education, sports**, and even, increasingly, in**nonprofit organizations**.

And, importantly, **students are drawn to Operational Research** because of its scope and great job opportunities!

For the Love of **OR**

When were you first captivated by OR?

From my first university course on the subject to my first projects in industry - working in the high tech defense sector on naval submarines in Newport, Rhode Island, I was drawn to the power of the subject, especially when combined with computing.

Off to Grad School for a PhD

While working in high tech defense consulting I realized that I did not like having a boss. I commuted, ran marathons, and worked full time while taking courses for my Master's at Brown.

Dr. Stella Dafermos was the only female professor at the time in either Engineering or Applied Mathematics at Brown University. I became her first PhD student.

EQUILIBRIUM MODELING, ANALYSIS AND COMPUTATION: THE CONTRIBUTIONS OF STELLA DAFERMOS

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(Received June 1990; accepted August 1990)

This memorial tribute to the late Stella Dafermos summarizes her contributions to equilibrium modeling, analysis, and computation, and provides a list of her published papers.

On April 5, 1990, with the death at 49 of Stella Dafermos, Professor of Applied Mathematics and Engineering at Brown University, Providence, Rhode Island, the operations research community lost one of its early woman doctorates. Throughout her quarter-century career she dedicated herself to developing rigorous mathematical formulations for modeling, analyzing and making computations related to competitive equilibrium systems that spanned applications from congested urban transportation networks to multicommodity trade. Beginning with her 1968 doctoral dissertation, "Traffic Assignment and Resource Allocation in Transportation Networks," directed by F. T. Sparrow at Johns Hopkins University, which focused on the study of system-optimized and user-optimized transportation networks, she initiated a theme of advancement of methodologies by which the behavior of complex systems could be captured and studied.

EQUILIBRIUM MODELING

In her first paper, based on her thesis and published in 1969, she proposed convergent equilibration algorithms that simulated the adjustment behavior of travelers on a congested network operating in their own self-interest in choosing their routes. The governing equilibrium conditions, due to Wardrop, reflected that only the minimum cost routes connecting each origin/destination pair would be used. These algorithms took advantage of the problem structure and were later extended in papers published in 1971 and 1972 to network models that allowed for interaction among users of the system via the link cost functions. In her 1969 paper she also focused on stability issues, which began the theme of qualitative analysis of equilibrium patterns that was also to pervade her scholarly work.

These network equilibrium models, as well as the integrated models that allowed for both location and route choice, developed in her paper of 1976, were formulated as optimization problems, with the observation that the equilibrium conditions governing these problems were actually the Kuhn-Tucker conditions of an appropriately constructed optimization problem. Interestingly, parallel to these developments in nonlinear networks, the economics community was reformulating spatial price equilibrium problems, in which commodities are produced, consumed and traded, subject to transportation or transaction costs, as optimization problems. However, the assumption required for such a transformation—that of *symmetry*, in which cross-effects of various interactions had to be identical—precluded the realistic modeling of multiple modes of transportation and different classes of users of a given system, as well as multiple commodities. Moreover, the objective function thus constructed, although convenient and essential given the state-of-the-art at the time, was artificial. Furthermore, equilibrium problems, by their very nature, involve more than a single agent and objective function, with interactions among the agents, and, hence, the objective functions being the rule rather than the exception. To overcome such shortcomings, a methodological advance was needed.

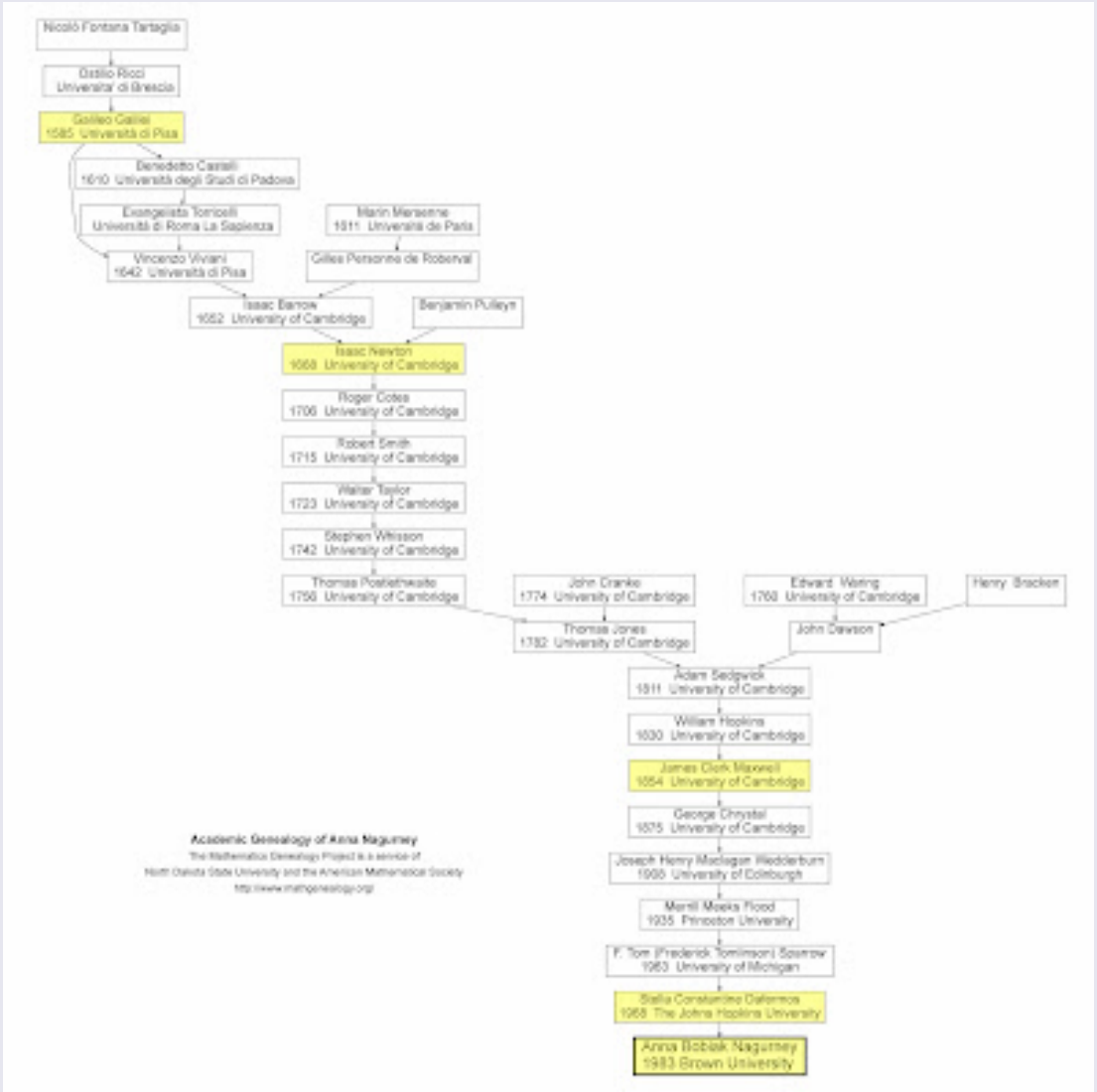
In 1980 Stella made a fundamental discovery by observing that the equilibrium conditions of the traffic assignment problem actually had the structure of a variational inequality problem. Although the theory of variational inequalities had been introduced over a decade earlier for the study of partial differential equations, the emphasis there was on infinite-dimensional problems arising in mechanics, and its use as a powerful tool for equilibrium analysis in operations research was left unrealized. Stella's identification of network equilibrium conditions with a variational inequality problem opened up new horizons for mathematical modeling, analysis and the efficient computation of more general equilibrium systems than had heretofore been possible. With this

Subject classifications: Economics: solution of equilibrium problems. Networks/graphs: equilibrium modeling and computation. Transportation: formulation and solution of mathematical problems.

Operations Research
Vol. 39, No. 1, January-February 1991 9
0030-364X/91/3901-0008 $01.25

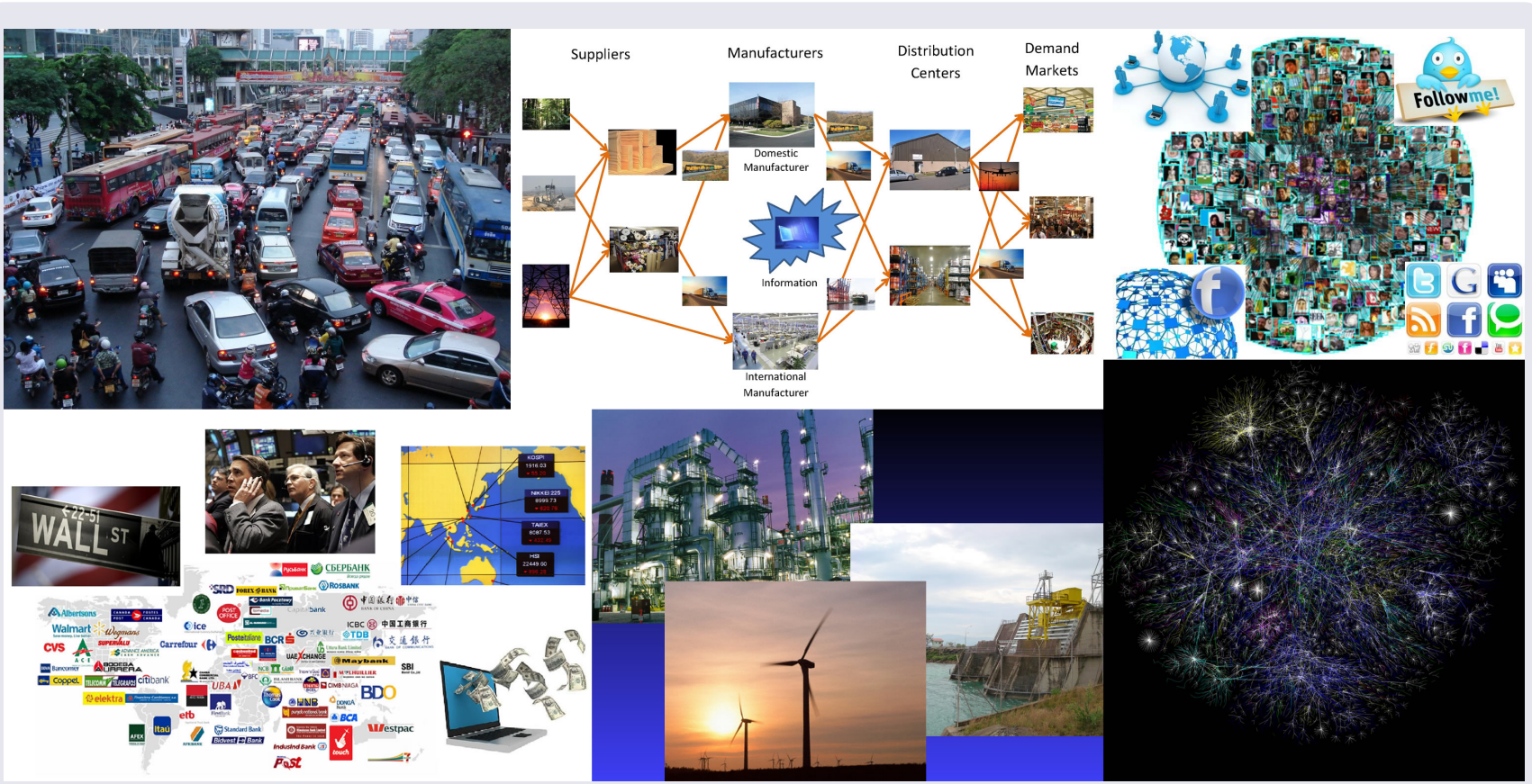
Stella was only the second female in the US to have received a PhD in OR and that was at Johns Hopkins University.

On the Shoulders of Giants - My Academic Genealogy - **Maxwell, Newton, and Galileo**



Network Systems and the Braess Paradox

I Work on the Modeling of Network Systems



And utilize optimization, game theory, and also dynamical systems to gain insights as to the behavior of stakeholders.

Some of My Books

Decentralized (Selfish) vs. Centralized (Unselfish) Behavior

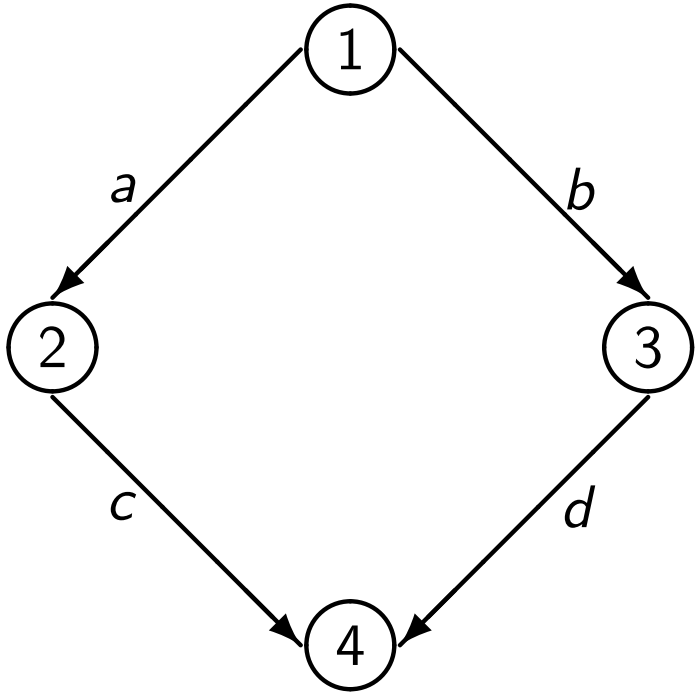
The Braess (1968) Paradox and User-Optimizing (U-O) Behavior

Assume a network with a single O/D pair (1,4). There are 2 paths available to travelers: $p_1 = (a, c)$ and $p_2 = (b, d)$.

For a travel demand of **6,** the equilibrium path flows are $x^*_{p_1} = x^*_{p_2} = 3$ and

The equilibrium path travel cost is

$C_{p_1} = C_{p_2} = 83.$



$$c_a(f_a) = 10f_a, \quad c_b(f_b) = f_b + 50,$$

$$c_c(f_c) = f_c + 50, \quad c_d(f_d) = 10f_d.$$

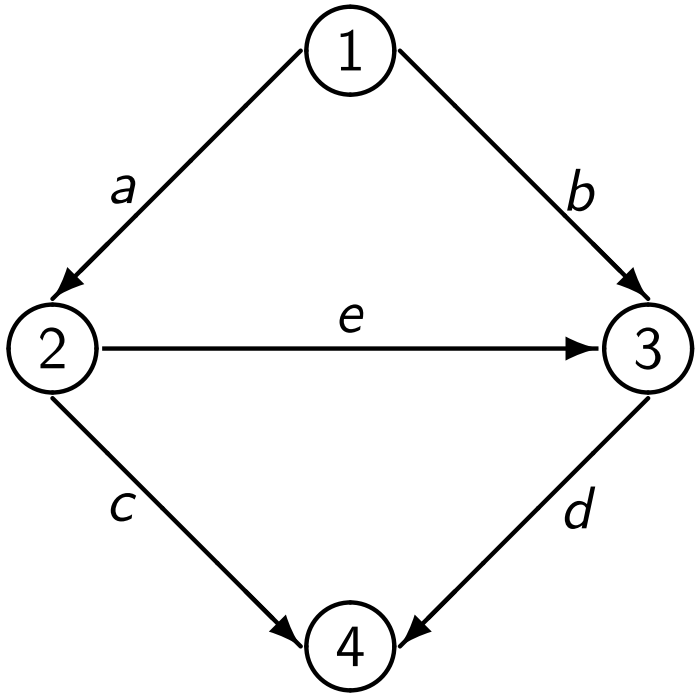
Adding a Link Increases Travel Cost for All!

Adding a new link creates a new path $p_3 = (a, e, d)$.

The original flow distribution pattern is no longer an equilibrium pattern, since at this level of flow the cost on path p_3, $C_{p_3} = 70$.

The new equilibrium flow pattern network is $x^*_{p_1} = x^*_{p_2} = x^*_{p_3} = 2$.

The equilibrium path travel cost: $C_{p_1} = C_{p_2} = C_{p_3} = 92$.



$c_e(f_e) = f_e + 10$

Travel cost / time increases for everyone!

We Translated the 1968 Braess Article from German to English.

"On a Paradox of Traffic Planning," D. Braess, A. Nagurney, and T. Wakolbinger, *Transportation Science* **39 (2005), pp 446-450.**

Über ein Paradoxon aus der Verkehrsplanung

Von D. Braess, Münster [1])

Eingegangen am 28. März 1968

Zusammenfassung: Für die Straßenverkehrsplanung möchte man den Verkehrsfluß auf den einzelnen Straßen des Netzes abschätzen, wenn die Zahl der Fahrzeuge bekannt ist, die zwischen den einzelnen Punkten des Straßennetzes verkehren. Welche Wege am günstigsten sind, hängt nun nicht nur von der Beschaffenheit der Straße ab, sondern auch von der Verkehrsdichte. Es ergeben sich nicht immer optimale Fahrzeiten, wenn jeder Fahrer nur für sich den günstigsten Weg heraussucht. In einigen Fällen kann sich durch Erweiterung des Netzes der Verkehrsfluß sogar so umlagern, daß größere Fahrzeiten erforderlich werden.

Summary: For each point of a road network let be given the number of cars starting from it, and the destination of the cars. Under these conditions one wishes to estimate the distribution of the traffic flow. Whether a street is preferable to another one depends not only upon the quality of the road but also upon the density of the flow. If every driver takes that path which looks most favorable to him, the resultant running times need not be minimal. Furthermore it is indicated by an example that an extension of the road network may cause a redistribution of the traffic which results in longer individual running times.

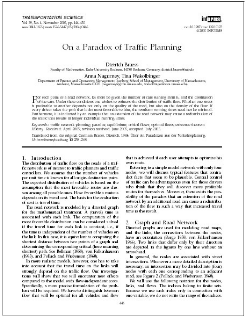
1. Einleitung

Für die Verkehrsplanung und Verkehrssteuerung interessiert, wie sich der Fahrzeugstrom auf die einzelnen Straßen des Verkehrsnetzes verteilt. Bekannt sei dabei die Anzahl der Fahrzeuge für alle Ausgangs- und Zielpunkte. Bei der Berechnung wird davon ausgegangen, daß von den möglichen Wegen jeweils der günstigste gewählt wird. Wie günstig ein Weg ist, richtet sich nach dem Aufwand, der zum Durchfahren nötig ist. Die Grundlage für die Bewertung des Aufwandes bildet die Fahrzeit.

Für die mathematische Behandlung wird das Straßennetz durch einen gerichteten Graphen beschrieben. Zur Charakterisierung der Bögen gehört die Angabe des Zeitaufwandes. Die Bestimmung der günstigen Stromverteilungen kann als gelöst betrachtet werden, wenn die Bewertung konstant ist, d. h., wenn die Fahrzeiten unabhängig von der Größe des Verkehrsflusses sind. Sie ist dann äquivalent mit der bekannten Aufgabe, den kürzesten Abstand zweier Punkte eines Graphen und den zugehörigen kritischen Pfad zu bestimmen [1], [5], [7].

Will man das Modell aber realistischer gestalten, ist zu berücksichtigen, daß die benötigte Zeit stark von der Stärke des Verkehrs abhängt. Wie die folgenden Untersuchungen zeigen, ergeben sich dann gegenüber dem Modell mit konstanter (belastungsunabhängiger) Bewertung z. T. völlig neue Aspekte. Dabei erweist sich schon eine Präzisierung der Problemstellung als notwendig; denn es ist zwischen dem Strom zu unterscheiden, der für alle am günstigsten ist,, und dem, der sich einstellt, wenn jeder Fahrer nur seinen eigenen Weg optimalisiert.

[1]) Priv.-Doz. Dr. Dietrich Braess, Institut für numerische und instrumentelle Mathematik, 44 Münster, Hüfferstr. 3 a.



TRANSPORTATION SCIENCE
Vol. 39, No. 4, November 2005, pp. 446–450
issn 0041-1655 | eissn 1526-5447 | 05 | 3904 | 0446

doi 10.1287/trsc.1050.0127
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On a Paradox of Traffic Planning

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For each point of a road network, let there be given the number of cars starting from it, and the destination of the cars. Under these conditions one wishes to estimate the distribution of traffic flow. Whether one street is preferable to another depends not only on the quality of the road, but also on the density of the flow. If every driver takes the path that looks most favorable to him, the resultant running times need not be minimal. Furthermore, it is indicated by an example that an extension of the road network may cause a redistribution of the traffic that results in longer individual running times.

Key words: traffic network planning; paradox; equilibrium; critical flows; optimal flows; existence theorem
History: Received: April 2005; revision received: June 2005; accepted: July 2005.

Translated from the original German: Braess, Dietrich. 1968. Über ein Paradoxon aus der Verkehrsplanung. *Unternehmensforschung* **12** 258–268.

1. Introduction

The distribution of traffic flow on the roads of a traffic network is of interest to traffic planners and traffic controllers. We assume that the number of vehicles per unit time is known for all origin-destination pairs. The expected distribution of vehicles is based on the assumption that the most favorable routes are chosen among all possible ones. How favorable a route is depends on its travel cost. The basis for the evaluation of cost is travel time.

The road network is modeled by a directed graph for the mathematical treatment. A (travel) time is associated with each link. The computation of the most favorable distribution can be considered solved if the travel time for each link is constant, i.e., if the time is independent of the number of vehicles on the link. In this case, it is equivalent to computing the shortest distance between two points of a graph and determining the corresponding critical (here meaning shortest) path. See Bellman (1958), von Falkenhausen (1963), and Pollack and Wiebenson (1960).

In more realistic models, however, one has to take into account that the travel time on the links will strongly depend on the traffic flow. Our investigations will show that we will encounter new effects compared to the model with flow-independent costs. Specifically, a more precise formulation of the problem will be required. We have to distinguish between flow that will be optimal for all vehicles and flow that is achieved if each user attempts to optimize his own route.

Referring to a simple model network with only four nodes, we will discuss typical features that contradict facts that seem to be plausible. Central control of traffic can be advantageous even for those drivers who think that they will discover more profitable routes for themselves. Moreover, there exists the possibility of the paradox that an extension of the road network by an additional road can cause a redistribution of the flow in such a way that increased travel time is the result.

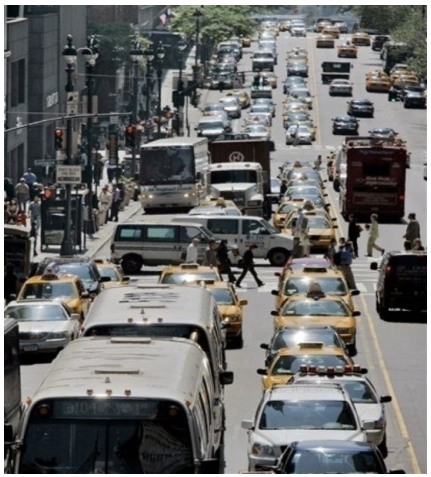
2. Graph and Road Network

Directed graphs are used for modeling road maps, and the links, the connections between the nodes, have an orientation (Berge 1958, von Falkenhausen 1966). Two links that differ only by their direction are depicted in the figures by one line without an arrowhead.

In general, the nodes are associated with street intersections. Whenever a more detailed description is necessary, an intersection may be divided into (four) nodes with each one corresponding to an adjacent road; see Figure 2 (Pollack and Wiebenson 1960).

We will use the following notation for the nodes, links, and flows. The indices belong to finite sets. Because we use each index only in connection with one variable, we do not write the range of the indices.

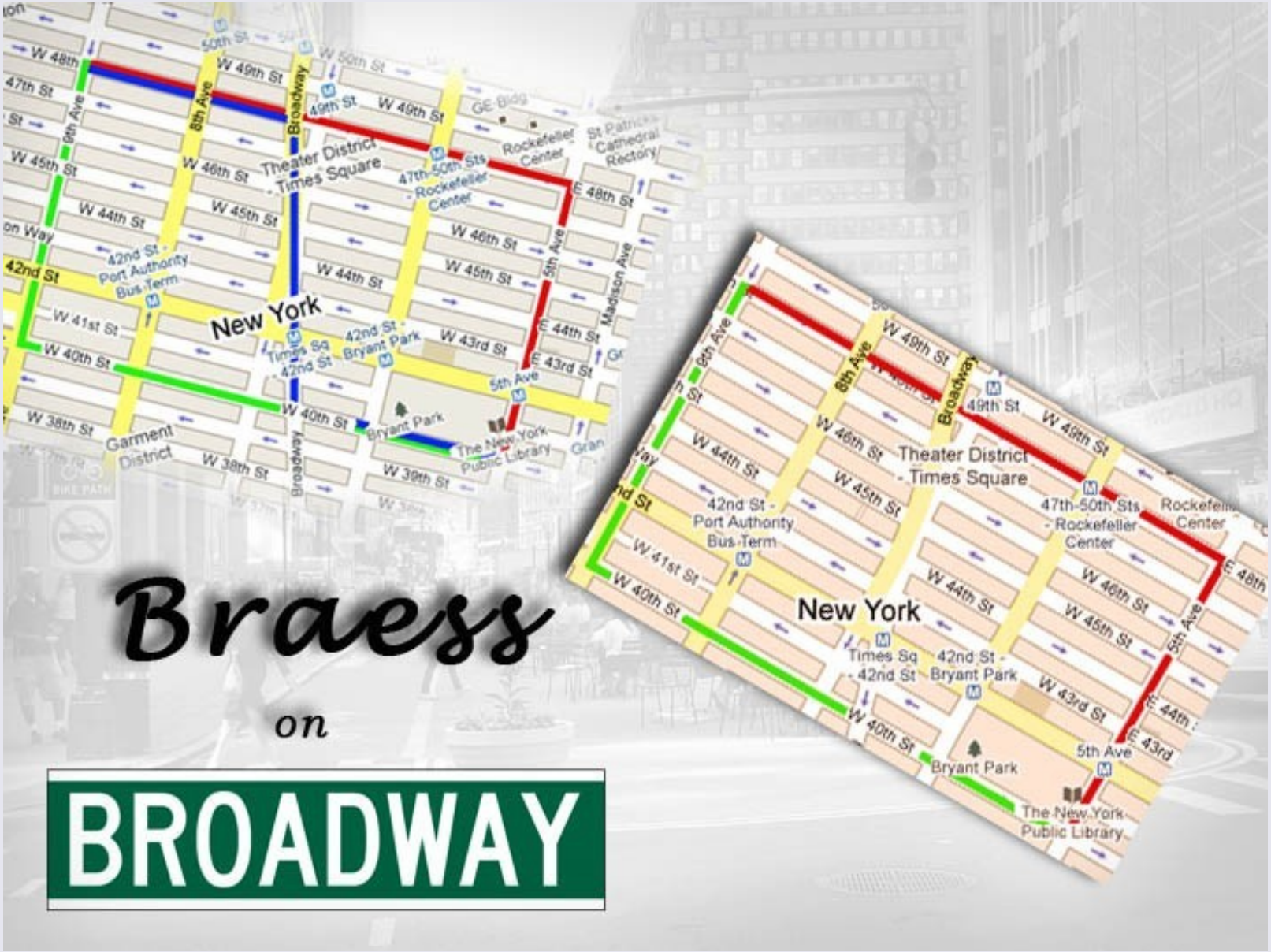
The Braess Paradox Around the World



1969 - Stuttgart, Germany - The traffic worsened until a newly built road was closed.

1990 - Earth Day - New York City - 42^{nd} Street was closed and traffic flow improved.

2002 - Seoul, Korea - A 6 lane road built over the Cheonggyecheon River that carried 160,000 cars per day and was perpetually jammed was torn down to improve traffic flow.

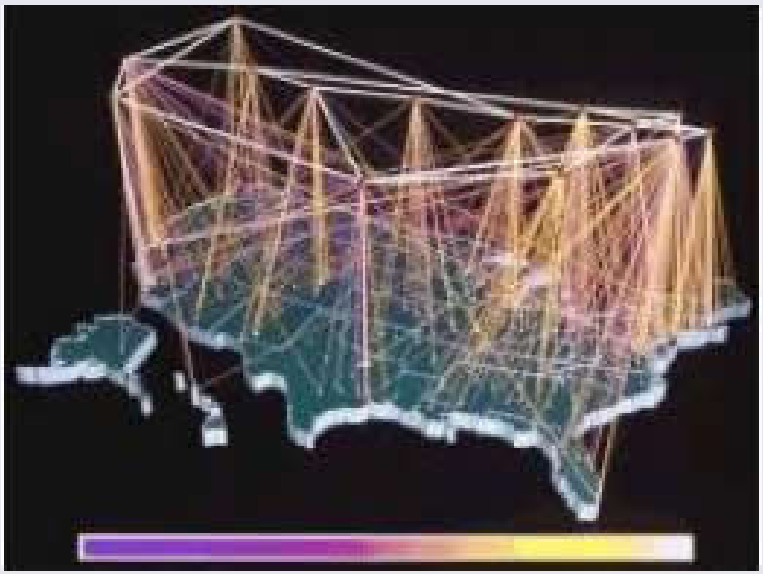

Braess
on
BROADWAY
New York
Theater District - Times Square
42nd St - Port Authority Bus Term
47th-50th Sts - Rockefeller Center
Times Sq - 42nd St
42nd St - Bryant Park
Bryant Park
The New York Public Library
Garment District
W 49th St
W 48th St
W 47th St
W 46th St
W 45th St
W 44th St
W 43rd St
W 42nd St
W 41st St
W 40th St
W 39th St
W 38th St
8th Ave
7th Ave
6th Ave
5th Ave
Broadway
Madison Ave
Newsboys
E 48th St
E 44th St
E 43rd St

Interview on Broadway for *America Revealed*

Under S-O behavior, the total cost in the network is minimized, and the new route p_3, under the same demand, would not be used.

The Braess paradox never occurs in S-O networks.

Other Networks that Behave like Traffic Networks



The Internet and electric power networks and even supply chains!

Congestion is Not a New Phenomenon

The study of the efficient operation of transportation networks dates to ancient Rome with a classical example being the publicly provided Roman road network and the time of day chariot policy, whereby chariots were banned from the ancient city of Rome at particular times of day.

Policies - Tolls and Congestion Pricing

Both William Vickrey, a Nobel laureate in Economic Sciences (in the 1950s), and Stella Dafermos (in the 1960s) with F. Tom Sparrow, constructed formulae for tolls, also, now known as congestion pricing.

Such policies have been implemented in several cities, including London, with the goal of reducing traffic congestion by altering the behavior of travellers / users of the transportation networks through pricing.

Representation of Supply Chains as Networks

Much of My Recent Research Has Been on Supply Chains

Characteristics of Supply Chains and Networks Today

- **large-scale nature** and complexity of network topology;
- **congestion**, which leads to nonlinearities;
- **alternative behavior of users of the networks**, which may lead to paradoxical phenomena;
- **possibly conflicting criteria associated with optimization**;
- **interactions among the underlying networks themselves**, such as the Internet with electric power networks, financial networks, and transportation and logistical networks;
- recognition of **their fragility and vulnerability**;
- policies surrounding networks today may have major impacts not only economically, but also **socially, politically, and security-wise**.

Representation of Supply Chains as Networks

By depicting supply chains as networks, consisting of nodes, links, flows (and also associated functions and behavior) we can:

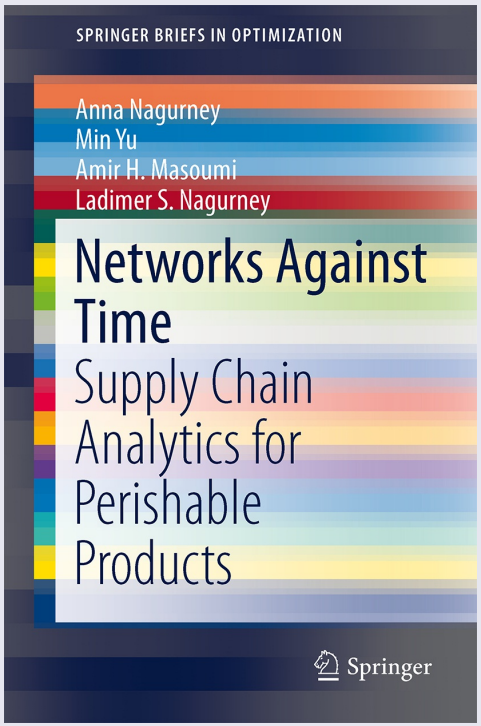
• see **commonalities** and **differences** among supply chain problems and even other network problems;

• avail ourselves, once the underlying functions (cost, profit, demand, etc.), flows (product, informational, financial, relationship levels, etc.), and constraints (nonnegativity, demand, budget, etc.), and the behavior of the decision-makers is identified, of **powerful methodological network tools for modeling, analysis, and computations**;

• build meaningful extensions using the graphical/network conceptualization.

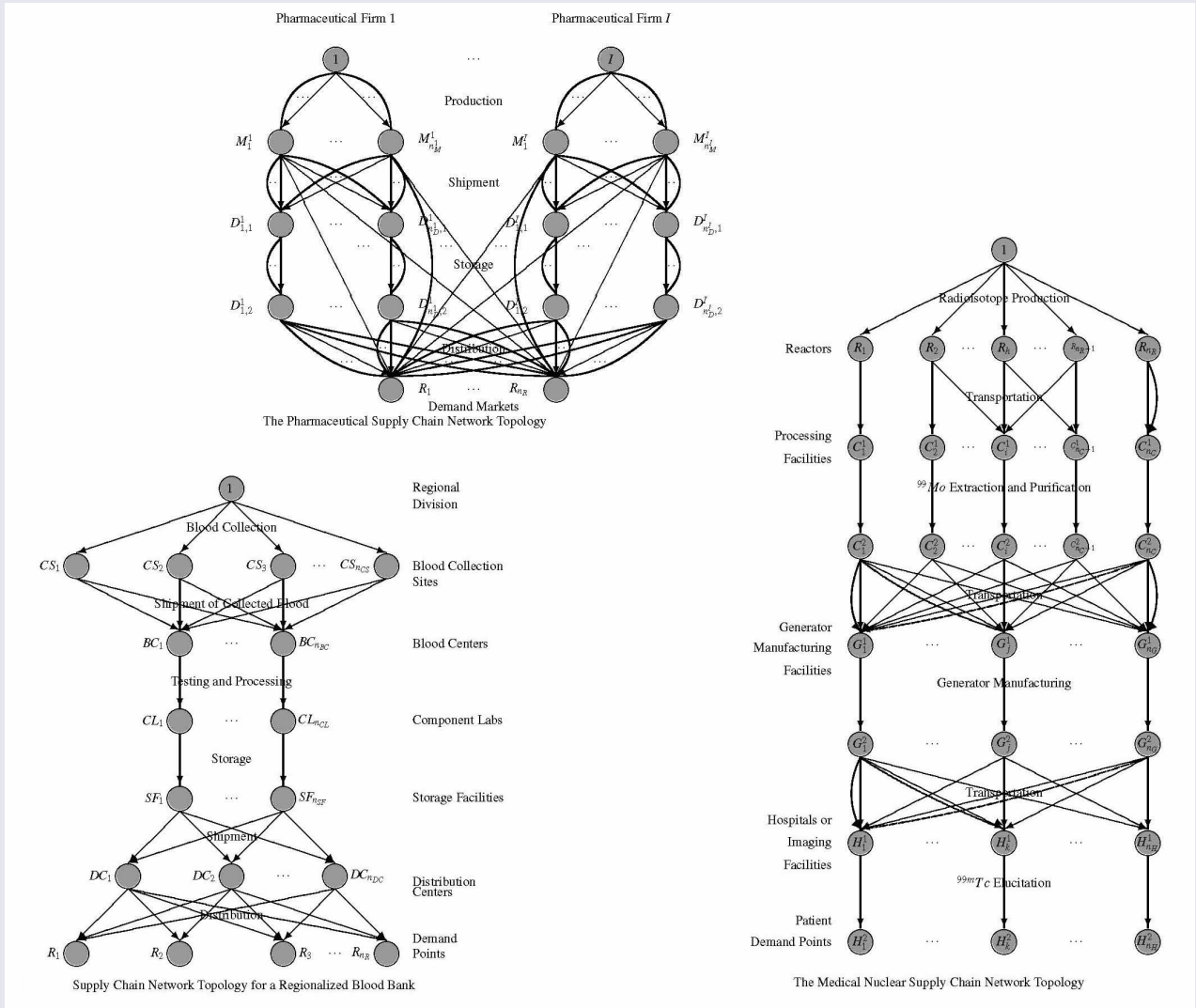
A Multidisciplinary Approach

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, and pharmaceuticals to food.

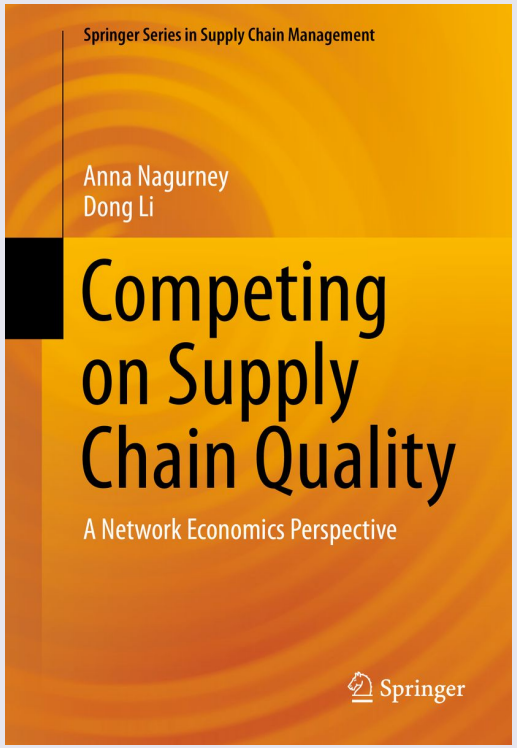


Some of the Supply Chain Network Topologies

Applications to pharmaceutical supply chains, blood and medical nuclear ones, and, of course, food.

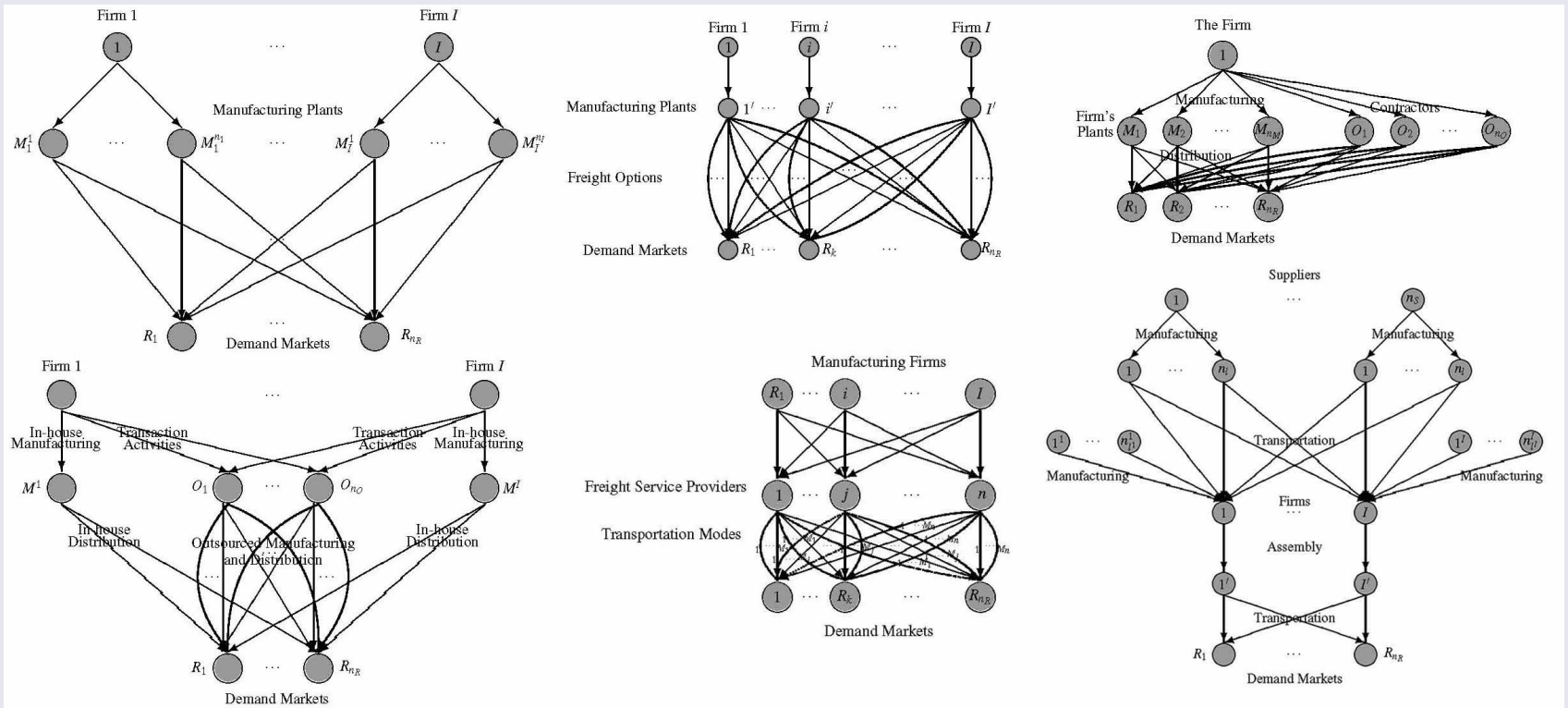


Research on Quality is Related to That on Perishability



Examples of product quality failures have included: • adulterated infant formula • inferior pharmaceuticals • defective airbags • defective ignition switches • bacteria-laden food • exploding smartphones, etc.

In the book, we present supply chain network models and tools to investigate, amongst other topics, information asymmetry, impacts of outsourcing on quality, minimum quality standards, applications to industries such as pharma, freight services and quality, and the identification of which suppliers matter the most to both individual firms' supply chains and to that of the supply chain network economy.



Food Supply Chains and Disruptions

Food Supply Chains

Food is essential to our health and well-being. During the Covid-19 pandemic, declared on March 11, 2020 by the World Health Organization, the associated supply chains suffered major disruptions. Various disruptions continue because of climate change, Russia's war on Ukraine, and other disasters.

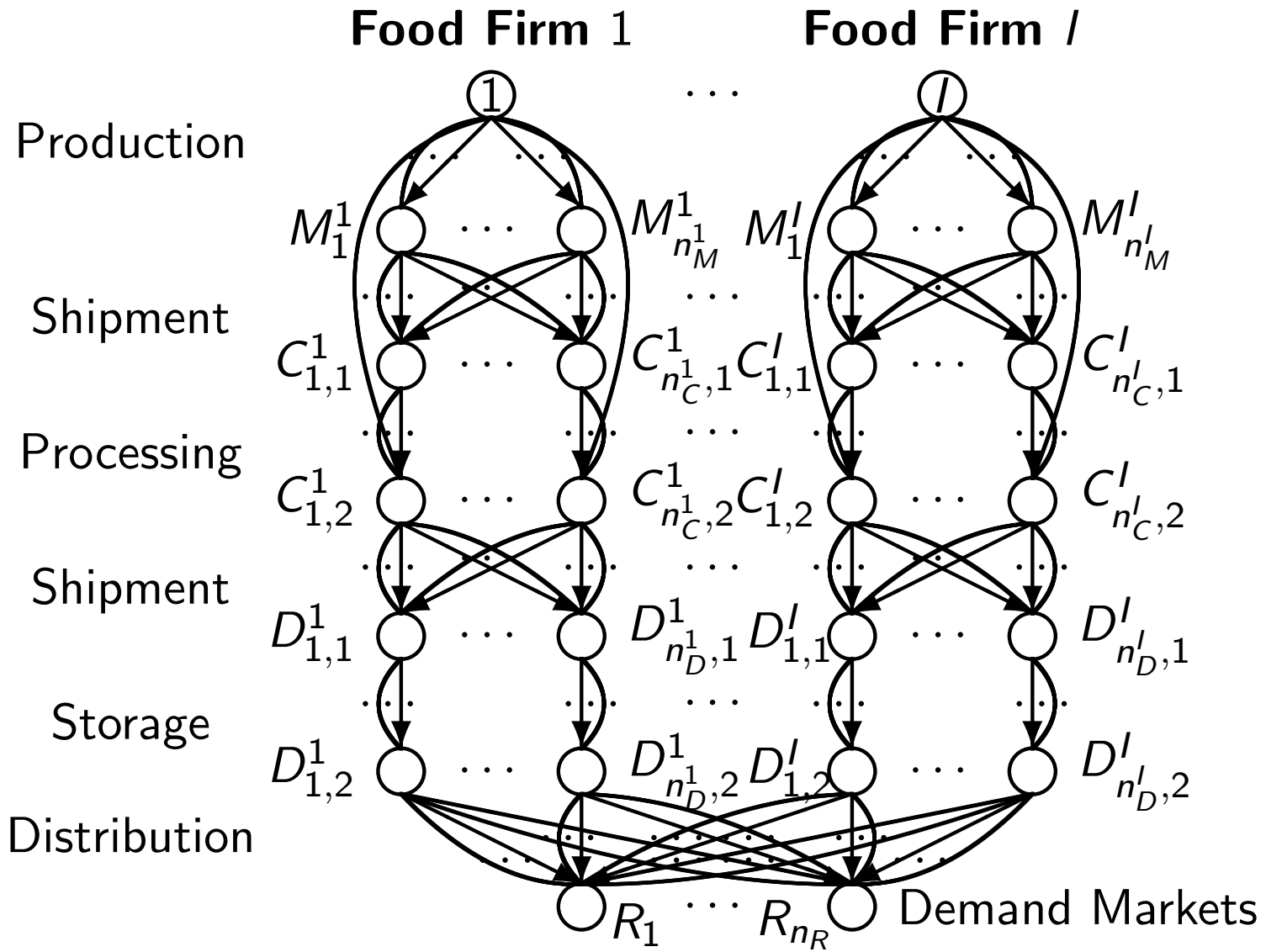
Fresh Produce Food Supply Chains

Our fresh produce supply chain network oligopoly model:

1. captures the deterioration of fresh food along the entire supply chain from a network perspective;
2. handles the time decay through the introduction of arc multipliers;
3. formulates oligopolistic competition with product differentiation;
4. includes the disposal of the spoiled food products, along with the associated costs;
5. allows for the assessment of alternative technologies involved in each supply chain activity.

M. Yu and A. Nagurney, "Competitive Food Supply Chain Networks with Application to Fresh Produce," *European Journal of Operational Research* **224(2) (2013), pp 273-282.**

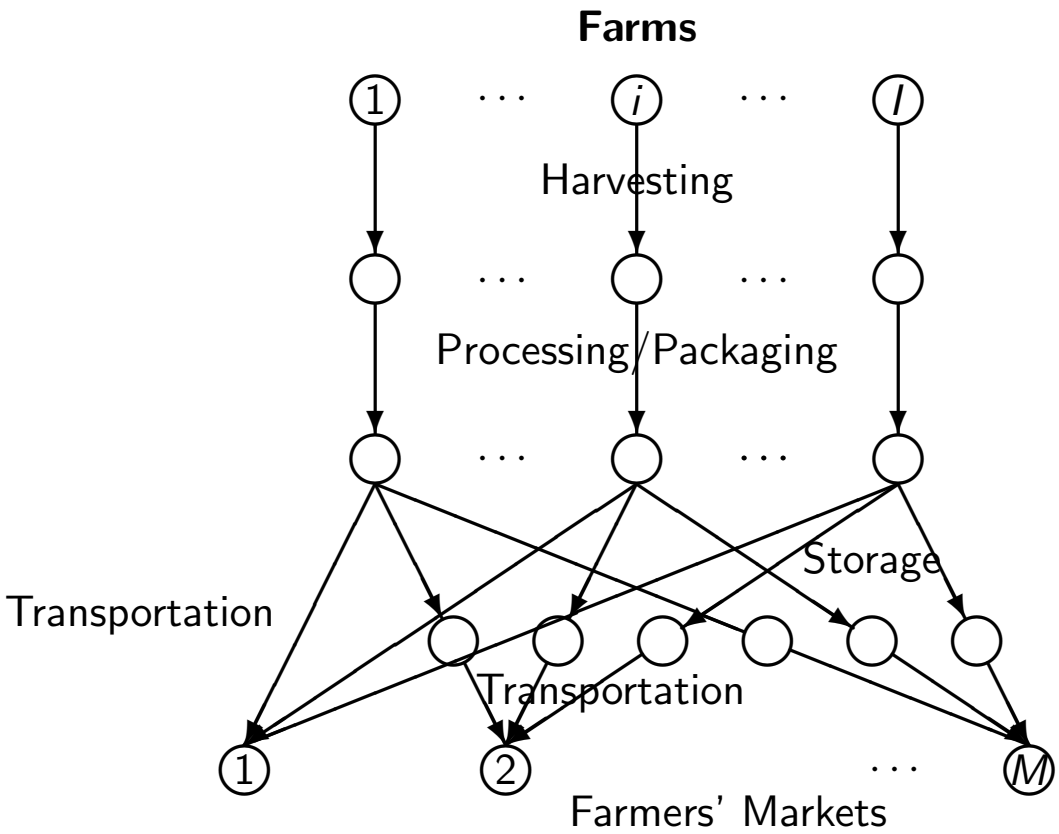
Fresh Produce Food Supply Chains

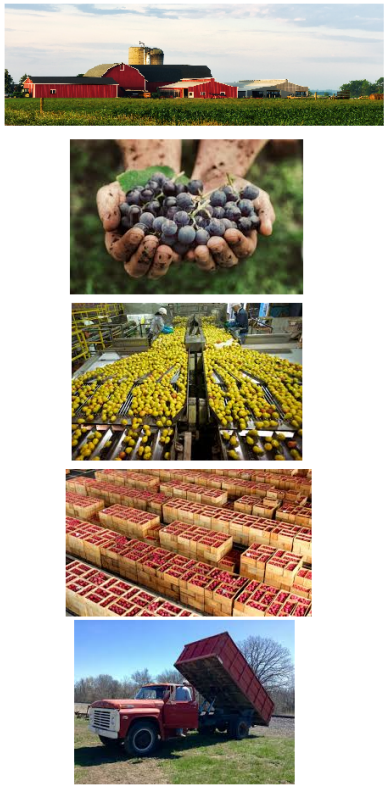


The Fresh Produce Supply Chain Network Topology

Farmers' Markets and Fresh Produce Supply Chains

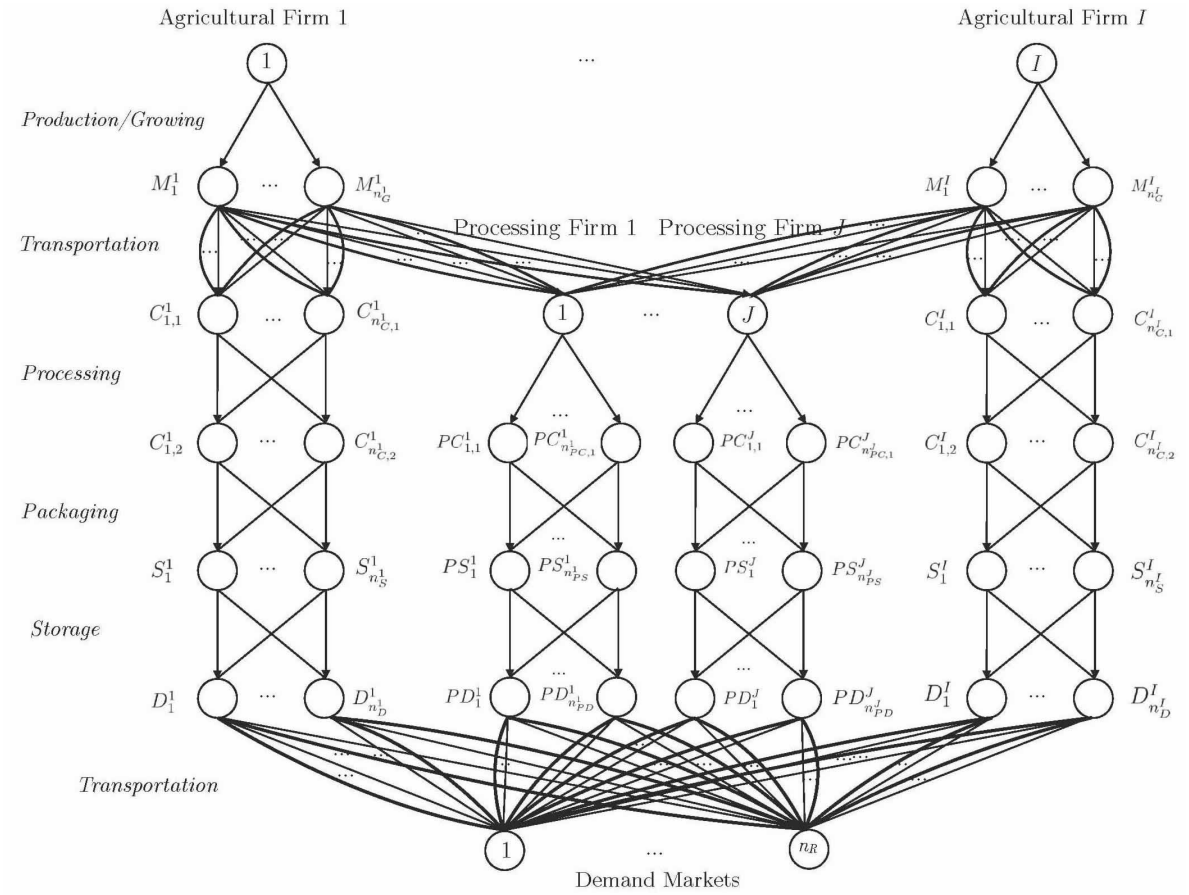
- The I farms compete **noncooperatively** in an **oligopolistic** manner.
- Products are differentiated based on **quality** at the farmers' markets.





D. Besik and A. Nagurney, "Quality in Competitive Fresh Produce Supply Chains with Application to Farmers' Markets," *Socio-Economic Planning Sciences* **60 (2017), pp 62-76.**

Integrated Supply Chain Network Model



D. Besik, A. Nagurney, and P. Dutta, "An Integrated Multitiered Supply Chain Network Model of Competing Agricultural Firms and Processing Firms: The Case of Fresh Produce and Quality," *European Journal of Operational Research* **307(1) (2023), pp 364-381.**

Food Supply Chain Disruptions Due to COVID-19

USA TODAY

AMERICA'S FOOD CHAIN

As coronavirus pandemic spikes orange juice sales, a Florida citrus grower gets squeezed

Janine Zeitlin, USA TODAY Network - Florida
Updated 8:07 p.m. EDT May 14, 2020

CNN

An Idaho farm is giving away 2 million potatoes because coronavirus has hurt demand

By Alisha Ebrahimji, CNN
Updated 1:33 PM ET, Thu April 16, 2020

Lacking seasonal workers, Italy elevates its long-shunned migrants

The Christian Science Monitor

THEDENVER CHANNEL.COM

Farms encountering guest worker shortage amid new coronavirus restrictions

REUTERS

Piglets aborted, chickens gassed as pandemic slams meat sector

The Washington Post
Democracy Dies in Darkness

The meat industry is trying to get back to normal. But workers are still getting sick — and shortages may get worse.

There are now more than 11,000 coronavirus cases tied to Tyson Foods, Smithfield Foods and JBS

Germany Struggles To Fill Its Farm Labor Shortage After Closing Its Borders

May 20, 2020 · 10:58 AM ET

ROB SCHMITZ

npr

It's All About People

A major research theme of ours in the COVID-19 pandemic (which continues) was the inclusion of labor in supply chains, using optimization and game theory.

ORMS TODAY informs membership magazine

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.

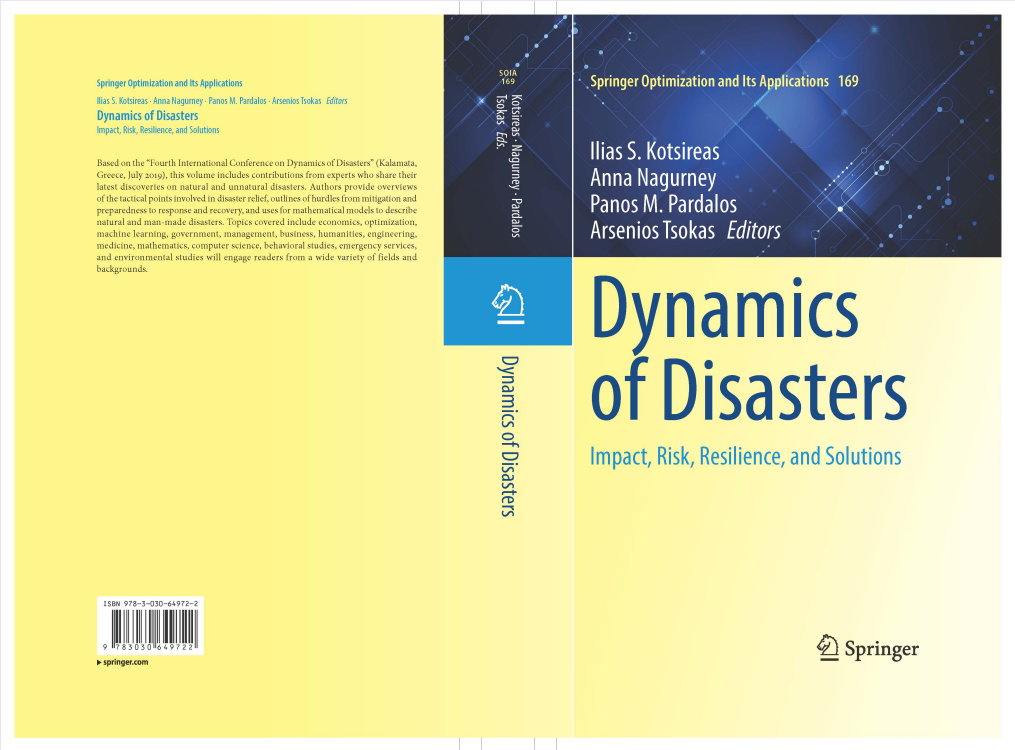
By Anna Nagurney

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

Perishable Food Supply Chain Network Model with Labor

"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.**



Perishable Food Supply Chain Network Model with Labor

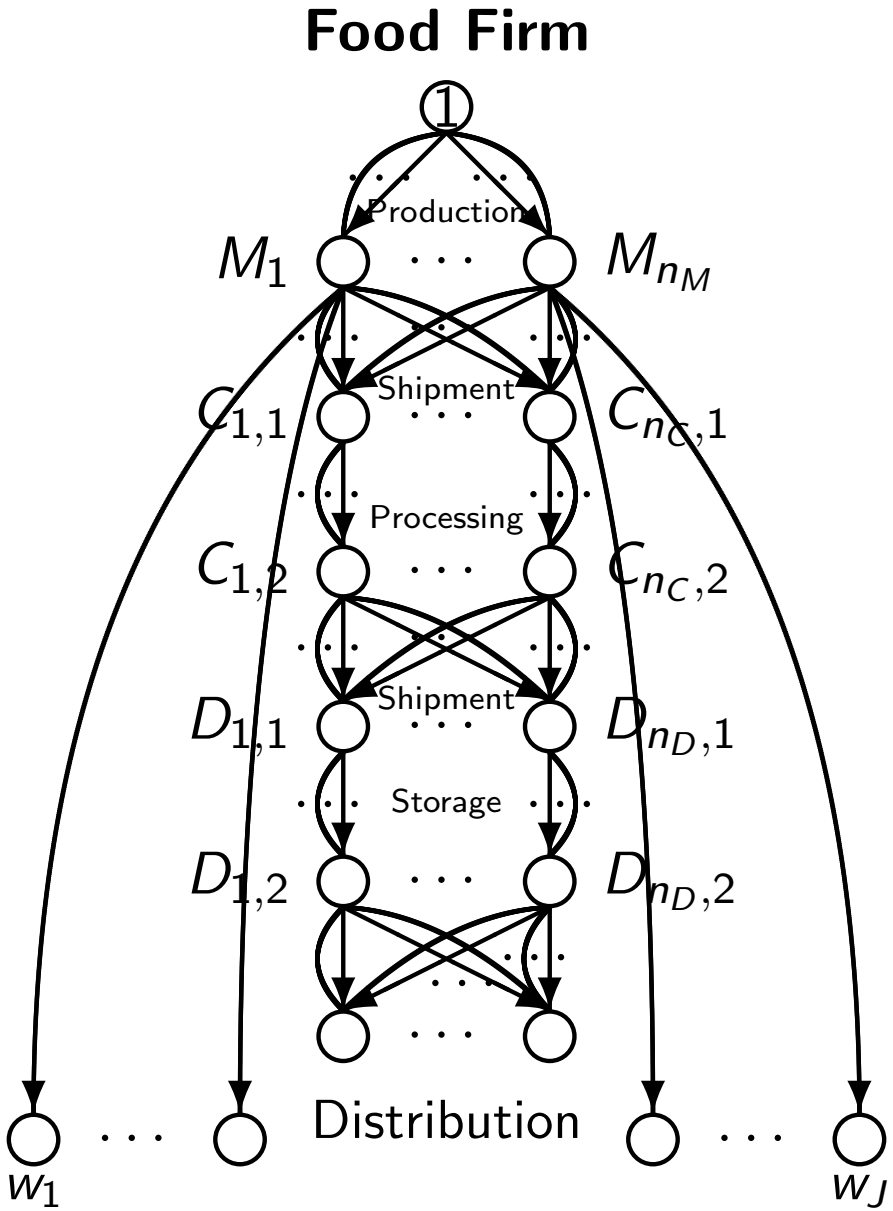


Figure: The Perishable Food Supply Chain Network Topology

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**.

Game Theory Supply Chain Network Modeling with Labor

In **"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**, a game theory model for supply chains with labor was constructed, under three different sets of constraints, building on our previous work.

European Journal of Operational Research 293 (2021) 880–891

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

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

ARTICLE INFO

Article history:
Received 17 August 2020
Accepted 23 December 2020
Available online 3 January 2021

Keywords:
Supply chain management
Labor
Game theory
Pandemic
Variational inequalities

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, Griffeth, & 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 Effeln (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 & Hufkurter, 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,

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https://doi.org/10.1016/j.ejor.2020.12.034
0377-2217/

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European Journal of Operational Research

Editors' Award

2021

Presented to

Anna Nagurney

in recognition of an outstanding contribution to the quality of the Journal with sincere thanks and very best wishes from the Editors of European Journal of Operational Research and the Directors of Elsevier B.V.

Prof. Roman Słowiński
Co-ordinating Editor of EJOR

Simon Jones
Publisher, Elsevier B.V.

Game Theory Supply Chain Network Model with Labor

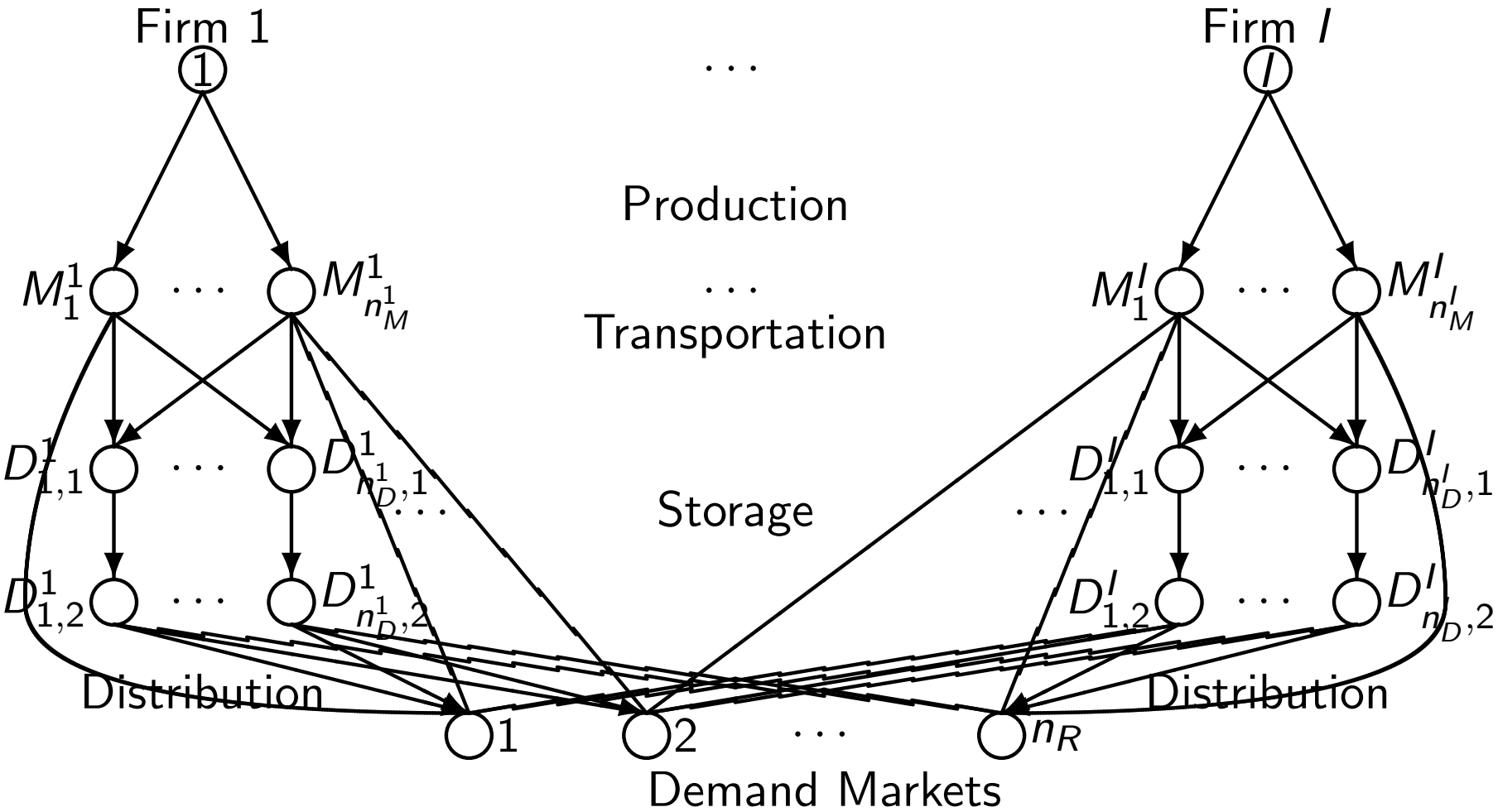


Figure: The Supply Chain Network Topology of the Game Theory Model with Labor

Numerical Experiments

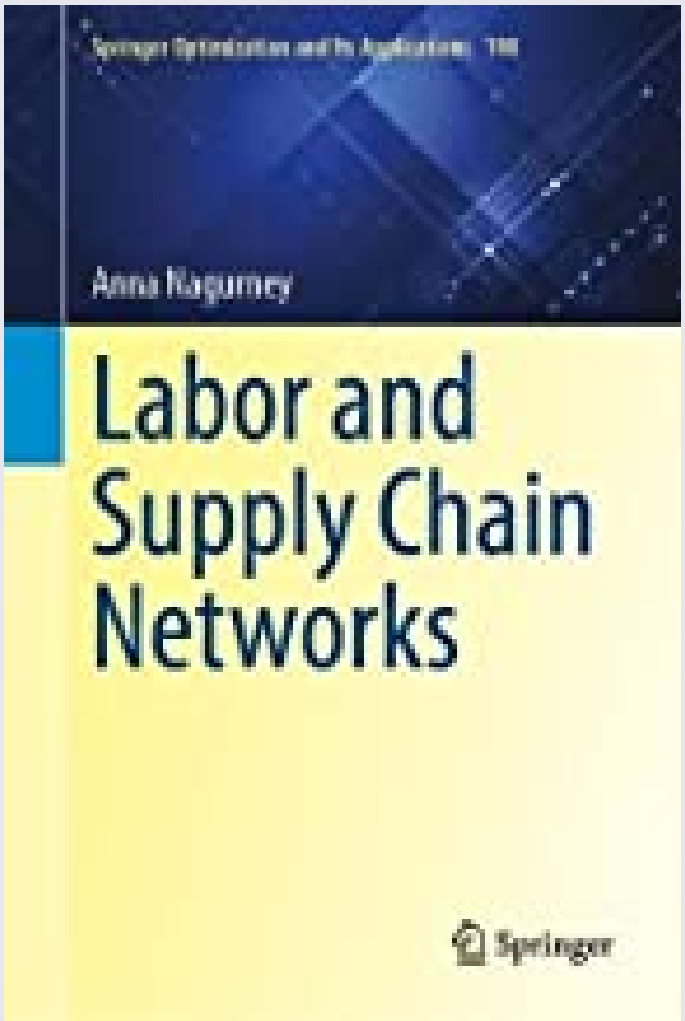
Our numerical examples are based on disruptions in migrant labor in the blueberry supply chain in the Northeast of the US in the summer of 2020.

- Disruptions in labor on a supply chain network link;
- Addition of a competitor;
- Modifications in demand price functions;
- Sensitivity analysis in terms of labor availability.

The full input and out data are available in our paper in the *European Journal of Operational Research.*

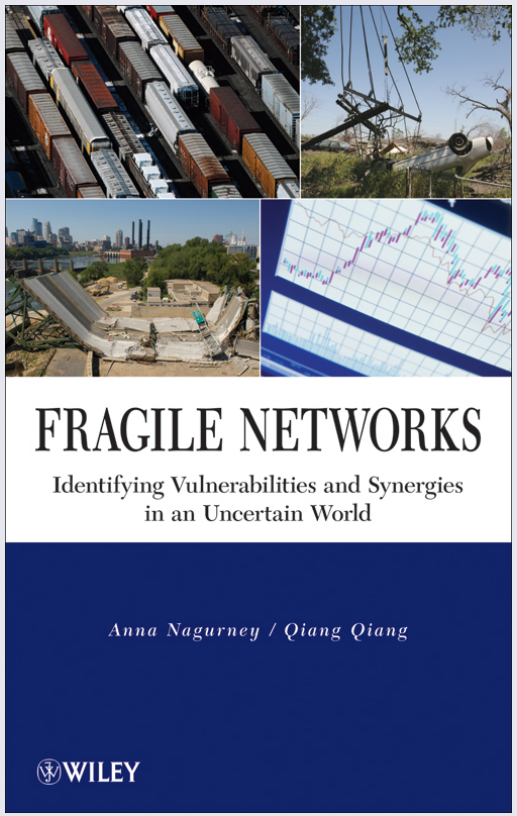
Farmers should do everything possible to secure the health of the workers at his production/harvesting facilities, so that the blueberries can be harvested in a timely manner and so that profits do not suffer. Keeping workers healthy, through appropriate measures, impacts the bottom line!

New Book



How I Became Interested in Cybersecurity

One of my books, written with a UMass Amherst Isenberg School PhD alum, was "hacked" and digital copies of it posted on websites around the globe.



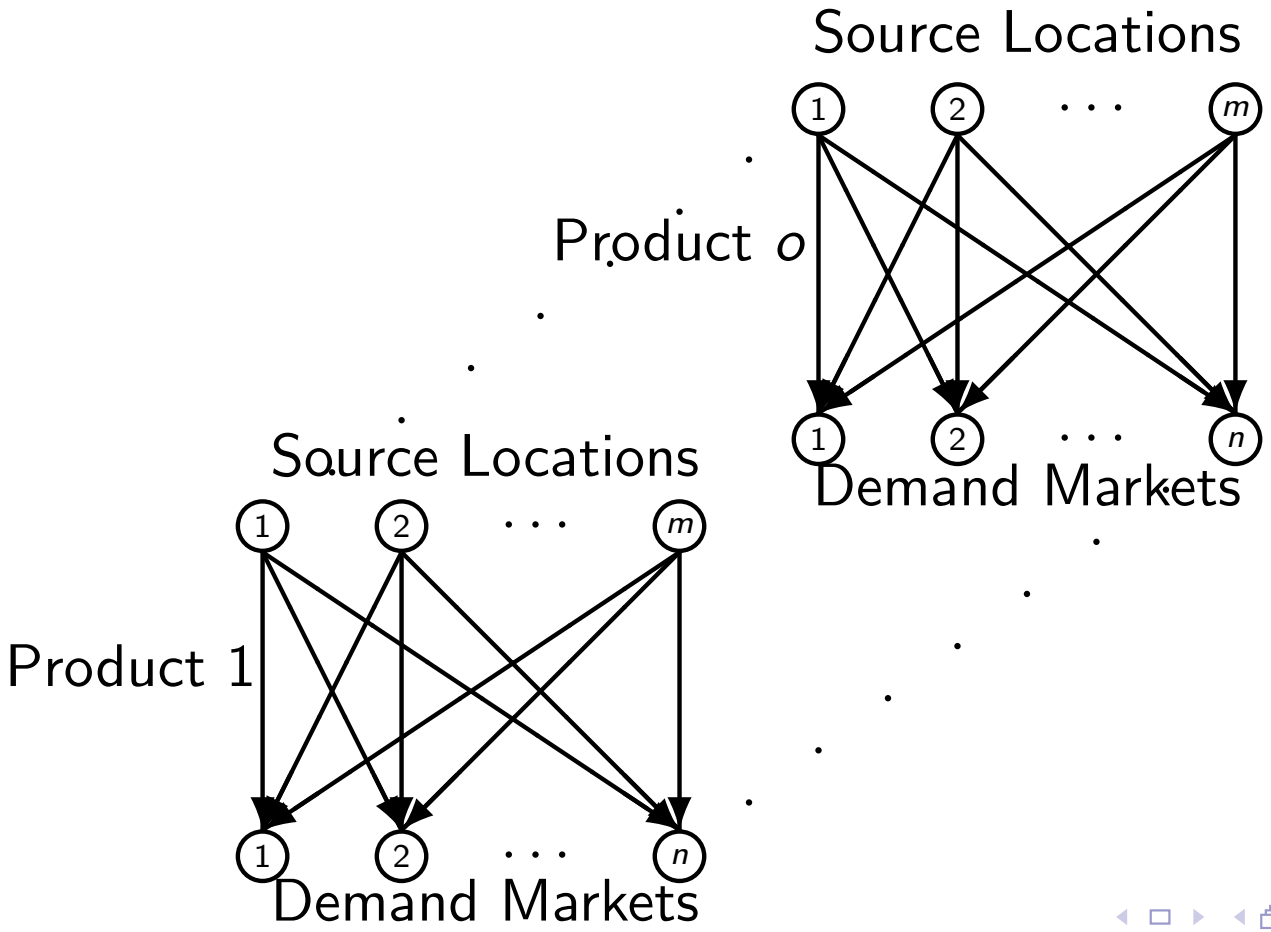
In a sense, this may be viewed as a compliment since clearly someone had determined that it has some sort of *value*.

The publisher John Wiley & Sons was notified and lawyers got involved but how do you contact and then influence those responsible for postings on rather anonymous websites?

Clearly, hackers go where there is money.

Perishability and Cybercrime in Financial Products

The paper, "A Multiproduct Network Economic Model of Cybercrime in Financial Services," A. Nagurney, *Service Science* 7(1) (2015) pp 70-81 provides insights into the perishability of value of credit cards.



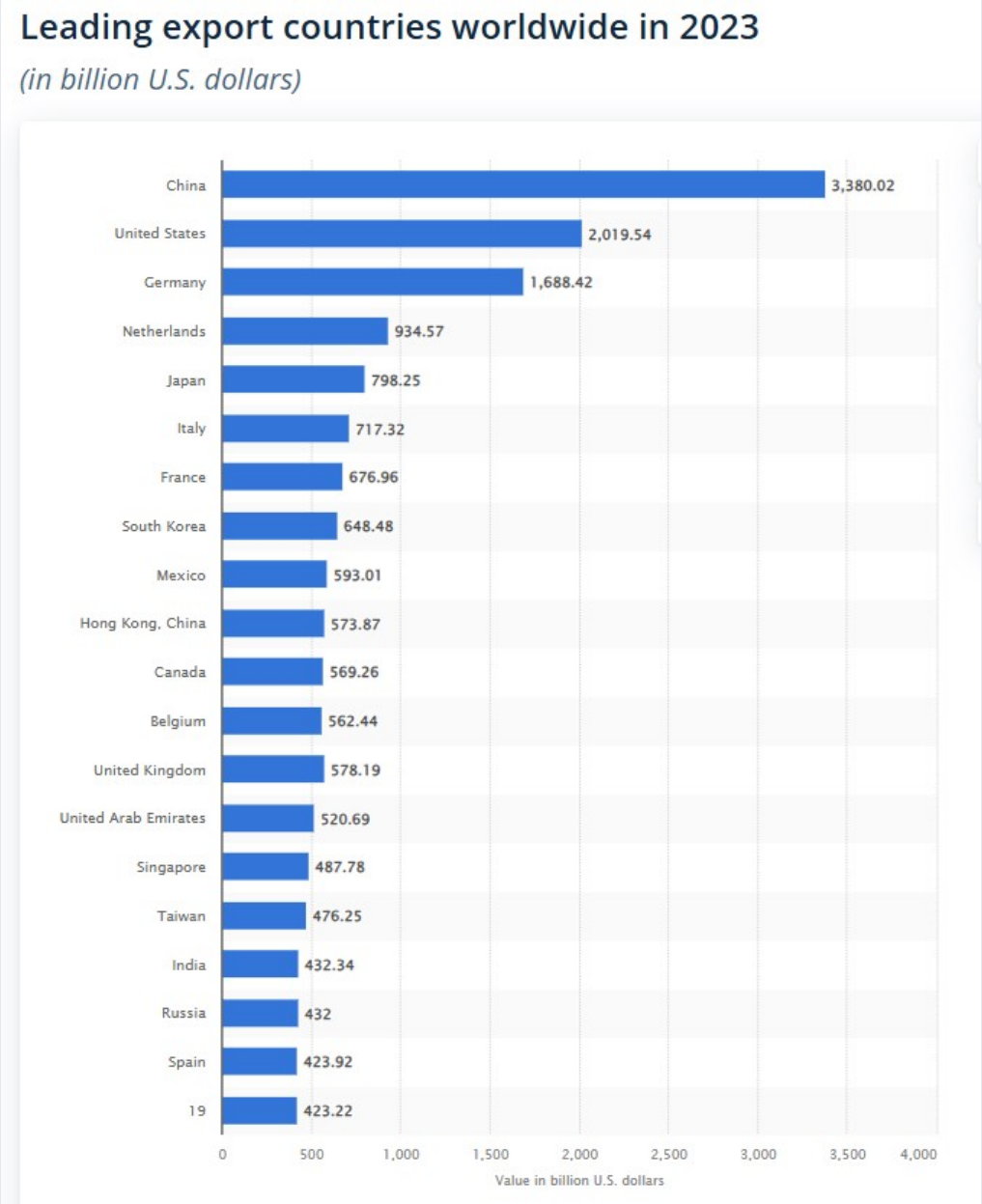
International Trade and Challenges

International Trade

International trade provides us with commodities throughout the year and has benefits for producers and consumers alike.

World's Biggest Importers

World's Biggest Exporters



Global Trade Policies

Examples of policy instruments that have been applied by governments to modify trade patterns include: tariffs, quotas, and a combination thereof - tariff rate quotas.

Tariffs Are Regularly in the News!

The imposition of tariffs by certain countries is leading to retaliation by other countries with ramifications across multiple supply chains, and a trade war.

With Higher Tariffs, China Retaliates Against the U.S.

The Yangshan Deep Water Port in Shanghai, China. The Chinese government said on Monday that it would raise tariffs on goods from the United States as of June 1, giving negotiators from the two countries time to strike a deal. Aly Song/Reuters

Trump's Tariffs Would Deal a Big Blow to the Auto Industry

Automakers and parts suppliers would struggle if President-elect Donald J. Trump followed through on his threat to impose 25 percent tariffs on imports from Canada and Mexico.

Nissan and other automakers are cutting thousands of jobs as they struggle to cope with sagging demand and a growing preference for hybrid and electric cars. Liberto Urena/Reuters

President-elect Donald J. Trump's threat to impose 25 percent tariffs on goods from Mexico and Canada sent shivers on Tuesday through the auto industry, which depends heavily on both countries for parts and manufacturing.

Global Trade Policies

We have been developing computable operational mathematical models that enable the assessment of the impacts of trade policy instruments such as tariff rate quotas on consumer prices, trade flows, as well as on the profits of producers/firms.

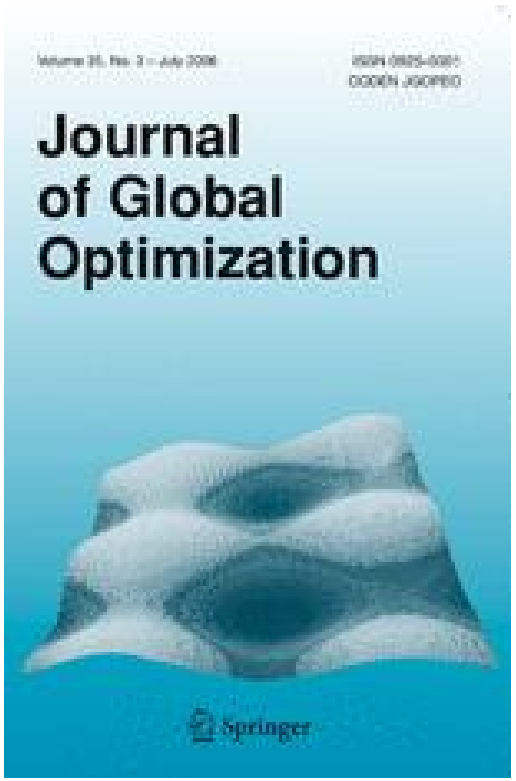
This is very challenging research!

Motivation

- A tariff rate quota (TRQ) is a **two-tiered tariff**, in which a lower **in-quota tariff** is applied to imports until a quota is attained and then a higher **over-quota tariff** is applied to all subsequent imports.
- **The Uruguay Round in 1996 induced the creation of more than 1,300 new TRQs.**
- **The world's four most important food crops: rice, wheat, corn, and bananas have all been subject to tariff rate quotas.**

An Example of Our Trade Policy Research

A. Nagurney, D. Besik, and L.S. Nagurney, "Global Supply Chain Networks and Tariff Rate Quotas: Equilibrium Analysis with Application to Agricultural Products, *Journal of Global Optimization* **75 (2019), pp 439-460.**



Another Example of Our Trade Policy Research

A. Nagurney, D. Besik, and J. Dong, "Tariffs and Quotas in World Trade: A Unified Variational Inequality Framework," *European Journal of Operational Research* **275(1) (2019), pp 347-360.**

International Agricultural Trade

International agricultural trade provides us with essential agri-food commodities throughout the year, ensuring our food security and simultaneously benefiting the farmers.

Disasters and Food Security

- **Climate change and COVID-19 impacted the affordability and accessibility of agri-food products around the globe.**
- **With the added disruptions of Russia's full-scale invasion of Ukraine on February 24, 2022, around 47 million people are estimated to have been added to the more than 276 million who were already facing food insecurity.**
- **Critical links such as the Panama Canal and the Red Sea and Suez Canal have been disrupted because of a drought affecting the former and Houthi attacks the latter.**

Acknowledgment

I acknowledge the partnership between the University of Massachusetts Amherst and the Kyiv School of Economics, which facilitated our research on international agricultural trade.

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TRANSPORTATION SCIENCE
Articles in Advance, pp. 1–22
ISSN 0041-1655 (print), ISSN 1526-5447 (online)

Proof Only

A Multiperiod, Multicommodity, Capacitated International Agricultural Trade Network Equilibrium Model with Applications to Ukraine in Wartime

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Received: August 26, 2023
Revised: February 25, 2024; July 11, 2024
Accepted: July 18, 2024
Published Online in Articles in Advance:
https://doi.org/10.1287/trsc.2023.0284

Abstract. The world is facing immense challenges because of increasing strife and the impacts of climate change with accompanying disasters, both sudden-onset as well as slow-onset ones, which have affected the trade of agricultural commodities needed for food security. In this paper, a multiperiod, multicommodity, international, agricultural trade network equilibrium model is constructed with capacity constraints on the production, transportation, and storage of agricultural commodities. The model allows for multiple routes between supply and demand country markets, different modes of transport, and storage in the producing and consuming countries as well as in the intermediate countries. The generality of the underlying functions, coupled with the capacity constraints, allow for the modeling of competition among agricultural commodities for production, transportation, and storage. The capacity constraints also enable the quantification of various disaster-related disruptions to production, transportation, and storage on the volumes of commodity flows as well as on the prices. A series of numerical examples inspired by the effects of Russia's full-scale invasion of Ukraine on agricultural trade is presented, and the results are analyzed to provide insights into food insecurity issues caused by the war.

Keywords: networks • international trade • spatial price equilibrium • agriculture • disruptions • Ukraine

1. Introduction

The full-scale invasion of Ukraine by Russia on February 24, 2022, has resulted in immense losses of lives and an increase in human suffering. It has severely impacted the economy of Ukraine with repercussions globally. Food insecurity is rising because the associated disruptions and destruction because of the war have been especially severe in the agricultural sector. Belgrave (2022) reports a rise of around 17% in the population facing food insecurity worldwide because of the full-scale invasion, equivalent to an increase of 47 million human beings facing food security issues. According to Rose (2022), the disruptions in the exports of Ukrainian grain can cost the global economy more than 1 a billion dollars.

The already strained food supply chains from the repercussions of the COVID-19 pandemic and climate change have been further hampered by the loss of arable land in Ukraine, known as the breadbasket of Europe, and the impeded transport of Ukrainian grain. The Food and Agriculture Organization (2022) of the United Nations estimates that between 20% and 30% of the arable land in Ukraine will remain idle because of mining and other damages because of the invasion, resulting in around a 40% decrease in the production of grain in Ukraine as compared with prewar production levels. In terms of the transportation of grain from Ukraine to the countries that heavily rely on these food supplies to meet the nutritional demands of their populations, especially Middle East and North Africa (MENA) countries such as Egypt and Lebanon, the blockade of the Ukrainian Black Sea ports, which used to handle around 90% of the grain exports from Ukraine (BBC 2022), caused a global shortage of grain and skyrocketed global food prices (Wageningen University & Research 2022). The twice-extended Black Sea Grain Initiative), facilitated by Turkey and the United Nations, allowed for the limited passage of grain shipments from selected Ukrainian ports on the Black Sea from August 1, 2022, onward (UN News 2022). The initiative resulted in around 33 million tons of Ukrainian grain being shipped to other countries (Nichols and Faulconbridge 2023); however, the export levels remained significantly lower than prewar levels because of the safety risks for the ships and slow inspections forced on the shipments (Ukrinska Pravda 2023).

Furthermore, as the war continues and with the news, as of July 17, 2023, that Russia has suspended the initiative, which has resulted in insurance companies

Quantification of International Trade Network Performance Under
uptions to Supply, Transportation, and Demand Capacity, and Exchange Rates in Disas

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Isenberg School of Management
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Revised March 2024

Prepared for: Dynamics of Disasters - From Natural Phenomena to Human Activity, I.S Kotsireas et al., Editors, Springer Nature Switzerland AG.

Abstract: Both sudden-onset and slow-onset disasters are causing disruptions to global trade, impacting the availability and affordability of commodities from agricultural to mineral ones. In this paper, we develop a multicommodity international trade network equilibrium model under disaster scenarios with distinct probabilities of the occurrence of the disasters and their impacts on the capacities associated with production, transportation, and consumption. The disaster scenarios can also affect the exchange rates. We state the governing equilibrium conditions and derive the variational inequality formulation in commodity path flow variables and Lagrange multipliers associated with the capacity constraints. For each disaster scenario, we construct an international trade network performance measure, followed by a unified performance measure that includes all the disasters and their probabilities. Robustness is then quantified as the difference between the network performance under no disruptions and the unified performance measure. An international trade network component performance indicator is also given to assess the impacts of the complete removal of trade network supply markets, demand markets, and/or transportation routes. The modeling framework is then illustrated through a series of numerical examples, motivated by Russia's war on Ukraine. The work is of relevance to decision-makers and policy-makers.

Key words: networks, international trade, disasters, disruptions, robustness, variational inequalities

European Journal of Operational Research 314 (2024) 1127–1142

Contents lists available at ScienceDirect

European Journal of Operational Research

Journal homepage: www.elsevier.com/locate/ejor

Innovative Applications of O.R.

Multicommodity international agricultural trade network equilibrium: Competition for limited production and transportation capacity under disaster scenarios with implications for food security

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ARTICLE INFO

Keywords:
Agriculture
Supply chains
Network equilibrium
International trade
Food security

ABSTRACT

The number of people affected by disasters, including man-made ones, is on the rise globally, with rising food insecurity being one of the most critical impacts. Disasters, both sudden-onset and slow-onset ones, can cause disruptions to the production and transportation of agricultural commodities. Having the tools that can quantitatively assess the changes in agricultural commodity shipment volumes and their prices under disruptions caused by disaster scenarios is of major importance. In this paper, we utilize the theory of variational inequalities as the methodology to construct a multicommodity international agricultural trade network equilibrium model, which contains novel features of capacities on the production and transportation of multiple agricultural commodities to capture competition. The model includes exchange rates and accounts for multiple routes and possibly distinct transportation modes and combinations. Theoretical results are given and an algorithm is proposed. A series of numerical examples, both illustrative and algorithmically solved ones, inspired by Russia's war on Ukraine, highlight the effects of reduced production and transportation capacities on food security in the Middle Eastern and North African (MENA) countries of Lebanon and Egypt. We also include sensitivity analysis results for exchange rates. The solutions reveal insights into the importance of the production and transportation capacities regarding food security, along with having multiple transportation routes that are cost-efficient as well as the importance of the magnitude of exchange rates.

1. Introduction

Our planet and people are being faced with immense challenges brought about by disasters ranging from those caused by natural phenomena (earthquakes, tornadoes, volcanic eruptions, tsunamis, hurricanes, floods, droughts, etc.) and those wrought by unnatural phenomena, caused by humans (wars, explosions, terrorist attacks, chemical spills, etc.). Some disasters, such as wildfires, may be caused by lightning (nature) or be man-made due to intentional, accidental, or because of lack of investment in mitigation reasons. Climate change is exacerbating the intensity of many disasters as well as the number of people affected by them. Disasters, both slow-onset and sudden-onset ones, can have an immense impact on nations, regions, businesses, organizations, and individuals and their families with long-lasting repercussions, including the escalation of economic and social costs.

A multiplicity of disasters can also impact food security. Even before Russia launched the full-scale invasion of Ukraine on February 24, 2022, climate change and COVID-19 had already impacted the affordability and accessibility of agri-food products around the globe. With the added disruptions of what has become a de facto war in Europe, according to Belgrave (2022), around 47 million people are estimated to have been added to the more than 276 million who were already facing food insecurity, corresponding to an increase of about 17% in the food-insecure population, mainly in the vulnerable communities of Sub-Saharan Africa and the Middle East. The Food and Agriculture Organization (FAO) of the United Nations (2022) reports that between 20 and 30 percent of the Ukrainian land previously used for cultivating winter crops will probably remain unsown due to the ongoing war. The reduction of lands used to harvest spring crops is projected at about 20%. Further exacerbated by the damaged production and storage facilities and the accessibility to essential inputs, such as seeds, fertilizer, fuel, etc., the decrease in Ukrainian cereal production is estimated at around 40% as compared to the output levels of 2021. In addition, there have been immense challenges in

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https://doi.org/10.1016/j.ejor.2023.11.013
Received 17 April 2023; Accepted 3 November 2023
Available online 7 November 2023

Journal of Global Optimization
https://doi.org/10.1007/s10898-023-01292-x

Exchange rates and multicommodity international trade: insights from spatial price equilibrium modeling with policy instruments via variational inequalities

Anna Nagurney[1] · Dana Hassani[1] · Oleg Nivievskyi[2] · Pavlo Martyshev[2]

Received: 29 December 2022 / Accepted: 2 May 2023

Abstract

In this paper, we construct a multicommodity international trade spatial price equilibrium model of special relevance to agriculture in which exchange rates are included along with policy instruments in the form of tariffs, subsidies as well as quotas. The model allows for multiple trade routes between country origin nodes and country destination nodes and these trade routes can include different modes of transportation and transport through distinct countries. We capture the impacts of exchange rates through the definition of effective path costs and identify the governing multicommodity international trade spatial price equilibrium conditions, which are then formulated as a variational inequality problem in product path flows. Existence results are established and a computational procedure presented. The illustrative numerical examples and a case study are inspired by the impacts of the war against Ukraine on agricultural trade flows and product prices. The modeling and algorithmic framework allows for the quantification of the impacts of exchange rates and various trade policies, as well as the addition or deletion of supply markets, demand markets and/or routes, on supply and demand market prices in local currencies, and on the volume of product trade flows with implications for food security.

Keywords Exchange rates · Spatial price equilibrium · International trade · Networks · Variational inequalities · Agriculture

1 Introduction

Exchange rates represent the value (price) of one currency relative to another currency. They are important economic parameters in international trade, with changes in the exchange rate affecting the decision-making of individuals, businesses, and governments. A separate

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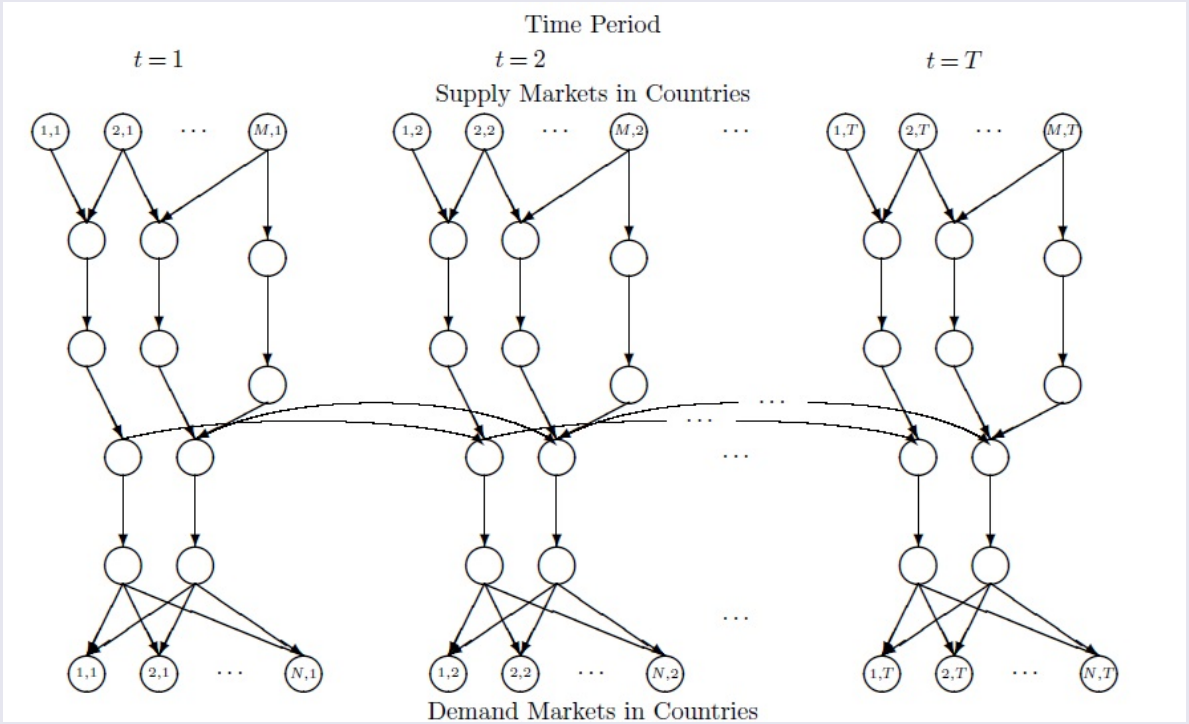
Published online: 15 May 2023

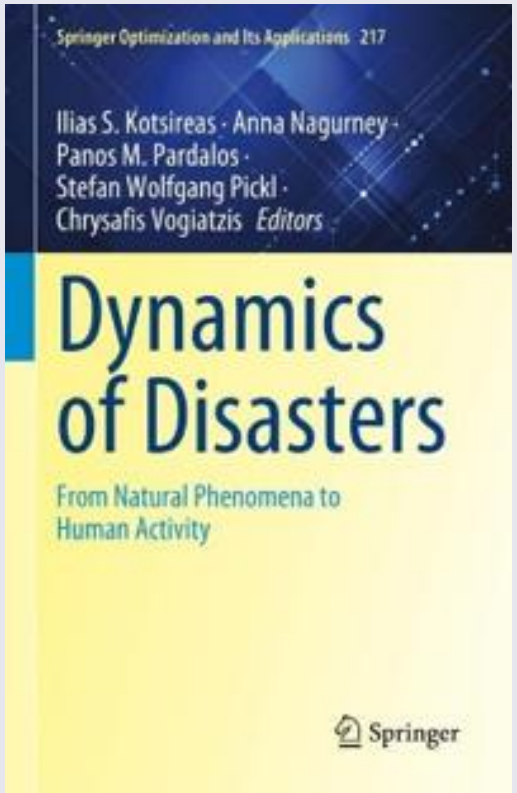
Springer

A Multiperiod International Agricultural Trade Network Topology



D. Hassani, A. Nagurney, O. Nivievskyi, and P. Martyshev, "A Multiperiod, Multicommodity, Capacitated International Agricultural Trade Network Equilibrium Model with Applications to Ukraine in Wartime," *Transportation Science (2024), Articles in Advance.*

New Edited Volume, In Press



In the edited volume is the paper, "Quantification of International Trade Network Performance Under Disruptions to Supply, Transportation, and Demand Capacity, and Exchange Rates in Disasters," by A. Nagurney, D. Hassani, O. Nivievskyi, and P. Martyshev.

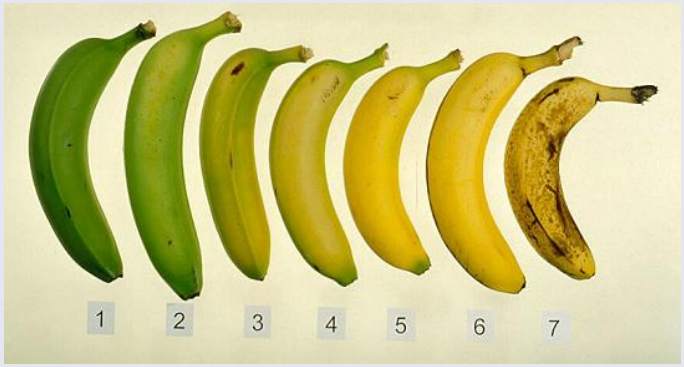
Some of the Insights Gained

In various studies, focusing on international trade of wheat and corn, and with countries such as Ukraine, and MENA countries of Egypt and Lebanon, we have demonstrated:

- The impacts of the Black Sea disruptions on food insecurity in terms of prices and quantity of trade flows of wheat and corn;
- The importance of efficient, effective transportation routes that include maritime transport on the Black Sea;
- How subsidies can assist farmers in wartime;
- The effects of arable land reduction on crop planting decision-making;
- The importance of various transportation links (and their ranking), among other findings.

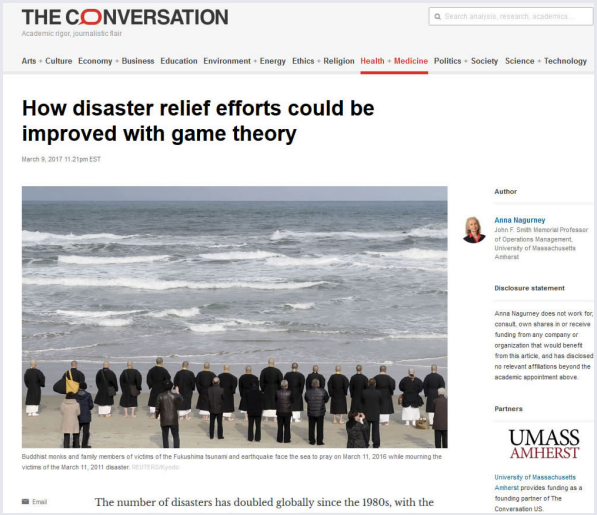
Some of the Insights Gained

Plus, our recent research has also investigated quantitatively the impacts of the drought in the Panama Canal on the banana trade to the US and Europe from South America, with the inclusion of quality deterioration due to time delays.



Making a Positive Impact

Writing OpEds



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Arts + Culture Economy + Business Education Environment + Energy Ethics + Religion Health + Medicine Politics + Society Science + Technology

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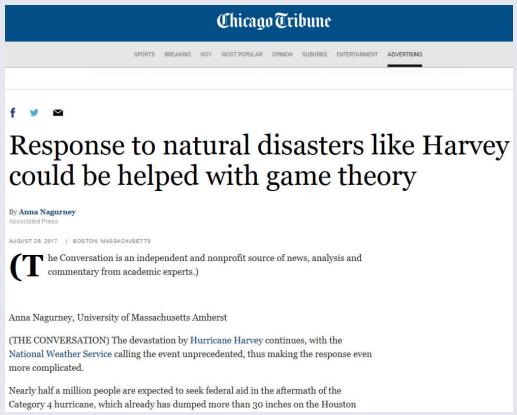
The number of disasters has doubled globally since the 1980s, with the



Chicago Tribune

SPORTS BREAKING HOY MOST POPULAR OPINION SUBURBS ENTERTAINMENT ADVERTISING

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

SALON VIDEO NEWS POLITICS ENTERTAINMENT LIFE

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

BIOMETRICS BORDER/IMMIG. BUSINESS CYBERSECURITY
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Disaster response

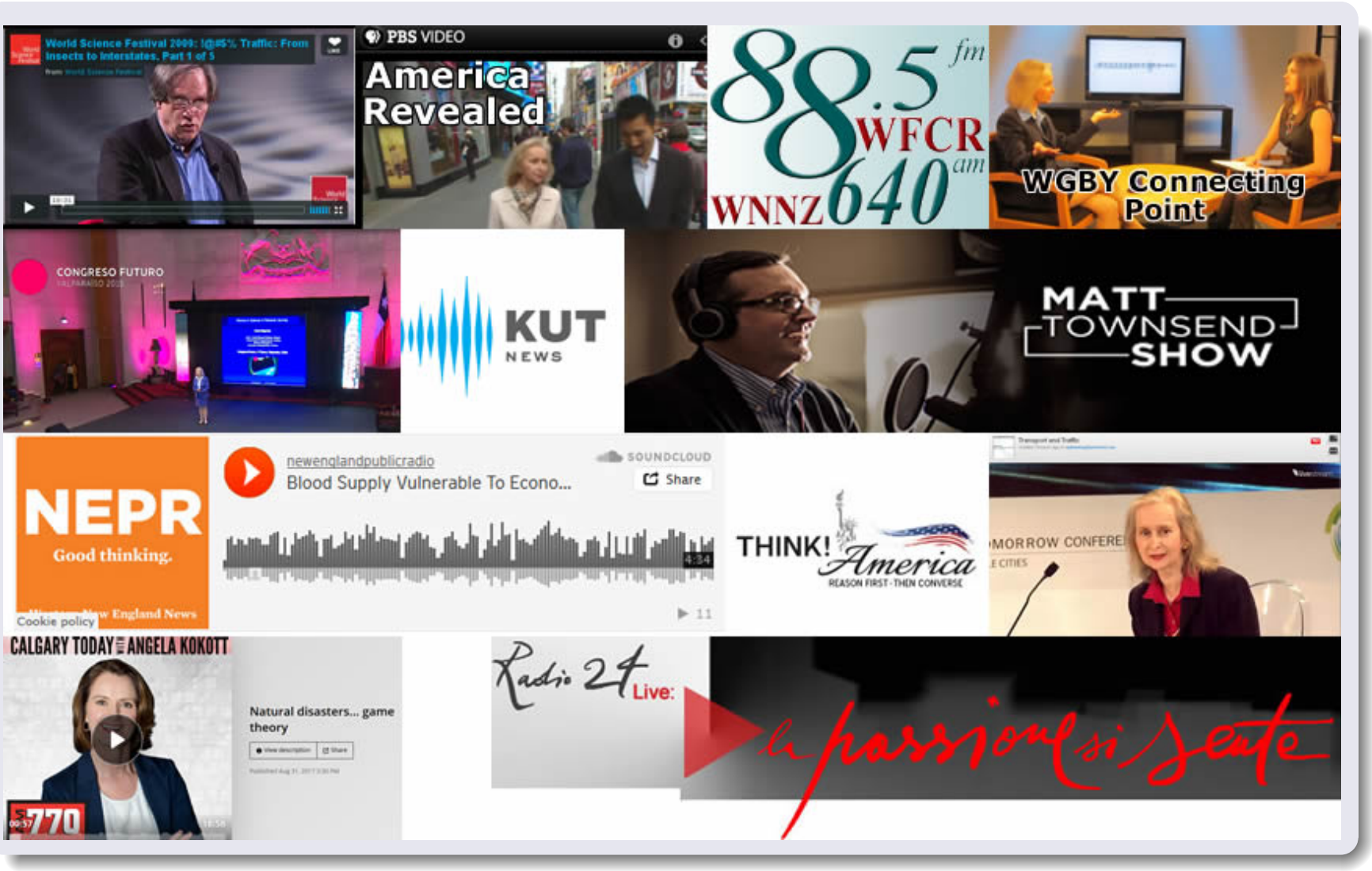
How disaster relief efforts could be improved with game theory

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



Writing OpEds in the Pandemic

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
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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

Analytics

DRIVING BETTER BUSINESS DECISIONS

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

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 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.

Some of My Media Interviews in the Pandemic

Writings After the Full-Scale Invasion

Operations Research for the Recovery and Reconstruction of Ukraine

By Anna Nagurney

OTHER VIEWS COMMENTARY

Ukraine will need 'Marshall Plan' to address human toll of war

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

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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

Continuing Disruptions to Trade Because of Houthi Attacks

THE CONVERSATION
Academic rigor, journalistic flair

Dockworkers pause strike after Biden administration's appeal to patriotism hits the mark

Published: October 4, 2024 3:55pm

Red Sea crisis: What it takes to reroute the world's biggest cargo ships

21 January 2024

BBC

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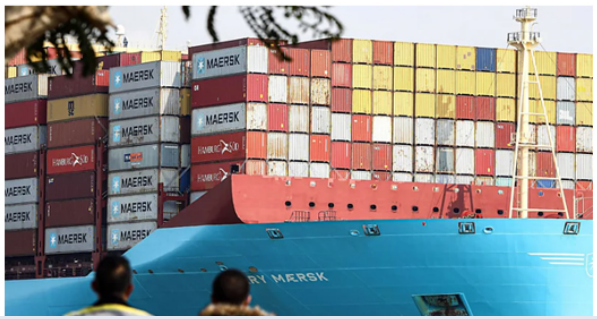
Chris Baraniuk
Features correspondent



ALJAZEERA

Houthi Red Sea attacks still torment global trade, a year after October 7

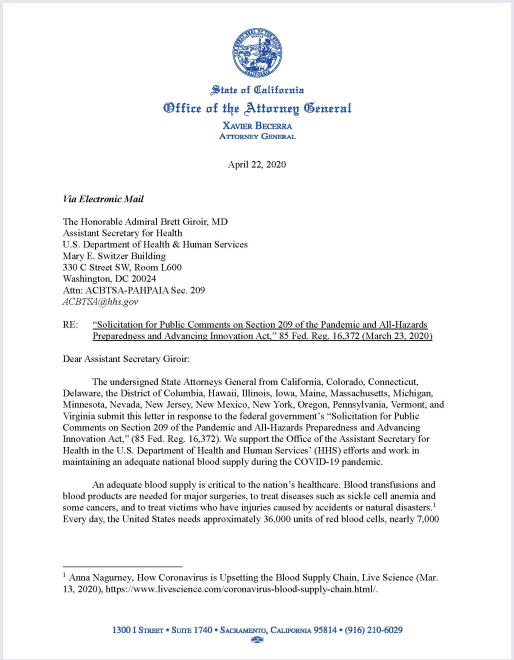
Yemen's rebel group has launched some 130 attacks in the crucial waterway since the start of the war in Gaza.

Impacting Policy

On April 22, 2020, a letter from California Attorney General Xavier Becerra to 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/.

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Hon. Brett Giroir
April 22, 2020
Page 7

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New Jersey Attorney General

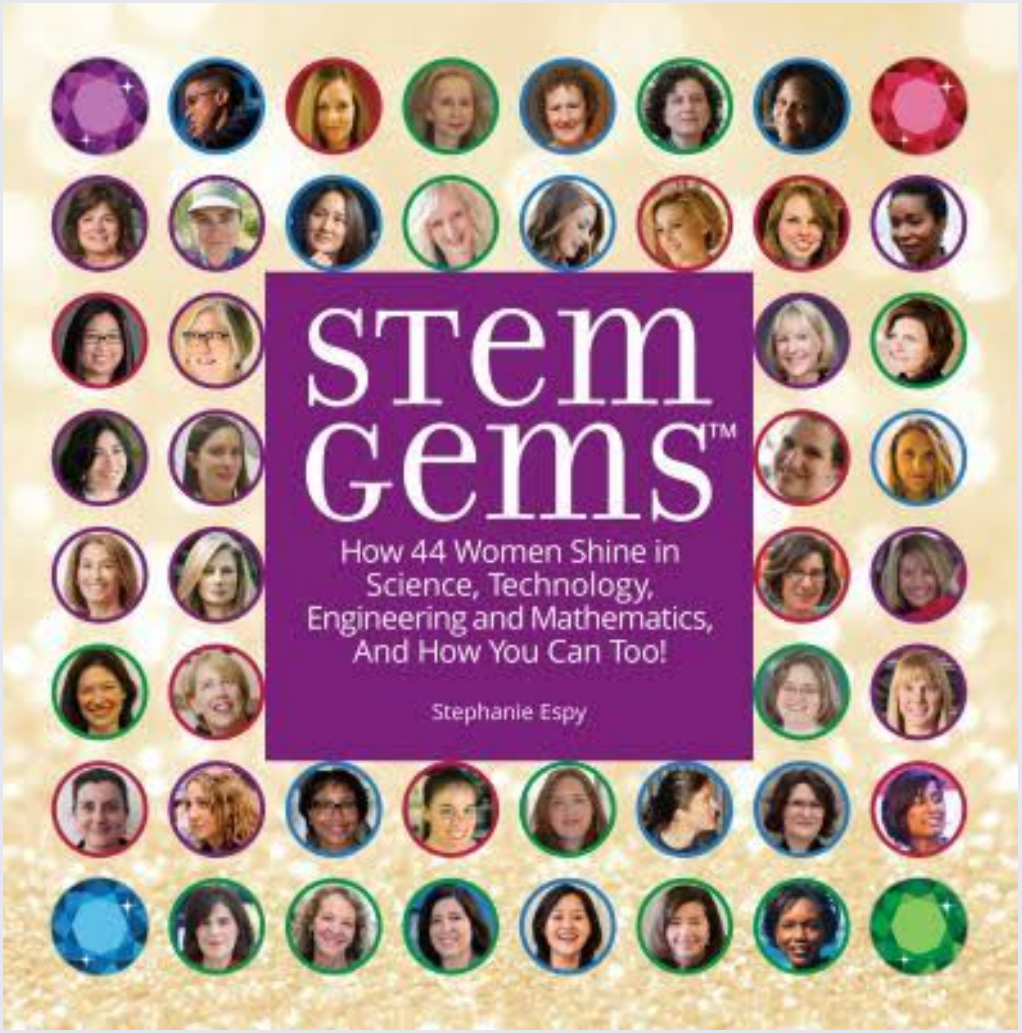
HECTOR BALDERAS
New Mexico Attorney General

LETITIA JAMES
New York Attorney General

Xavier Becerra, then CA Attorney General, is now the Secretary of Health and Human Services in the United States in President Biden's administration!

The Future is Bright But Investment is Needed

It is very important that we codify the history / herstory of OR for different age groups.



Thanks to The OR Society and JORS for the 1st Discussion Paper, Published in 2024

JOURNAL OF THE OPERATIONAL RESEARCH SOCIETY
2024, VOL. 75, NO. 6, 1011–1029
https://doi.org/10.1080/01605682.2024.2343343

DISCUSSION

OPEN ACCESS

Gender equality: opportunities and challenges for the OR community

Paula Carroll and Annunziata Esposito Amideo

School of Business, University College Dublin, Dublin, Ireland

ABSTRACT

There is a research gap on understanding gender equality issues in the OR discipline, and on the role of gender in OR participation and career progression. We apply a gender lens to the literature on the history of OR, reflecting on the origins of OR, the OR community, and the theory, methods and practice of OR. A gender lens aims to uncover hidden gender dimensions to bring gender issues into sharper focus. The review shows that women are largely invisible in the recorded history of OR. We use a survey instrument to capture the current OR community and extract insights on their careers by gender. Using a decision tree to understand factors that affect participation in OR, our findings are consistent with other studies: women perceive barriers to their participation and career progression, but the barriers are not as apparent to their male peers. Our paper offers novel contributions including a reflection on the history of OR through a gender lens, insights on the role of gender in OR careers, and a critical discussion of our findings. We aim to stimulate a conversation and encourage a discussion on the next steps toward innovative and cross-disciplinary research and applications at the gender/OR nexus.

ARTICLE HISTORY
Received 12 April 2023
Accepted 10 April 2024

KEYWORDS
History of OR; gender equality; OR/gender nexus; survey; decision tree

JOURNAL OF THE OPERATIONAL RESEARCH SOCIETY
2024, VOL. 75, NO. 6, 1030–1042
https://doi.org/10.1080/01605682.2024.2344969

COMMENTARY

OPEN ACCESS

Commentary on Carroll & Esposito Amideo "Gender Equality: Opportunities and challenges for the OR community"

Laura A. Albert[a], Annunziata Esposito Amideo[b], Julia Bennell[c], Sally Brailsford[d], Paula Carroll[b], Ruth Kaufman[e], Katherine Kent[f], Kathy Kotiadis[g], Martin Kunc[h], Anna Nagurney[i], Frances O'Brien[j], Graham Rand[k] and M. Grazia Speranza[l]

[a]University of Wisconsin-Madison, Madison, Wisconsin, USA; [b]University College Dublin, Dublin, Ireland; [c]Leeds University Business School, University of Leeds, Leeds, UK; [d]University of Southampton, Southampton, UK; [e]The Operational Research Society, London, UK; [f]Women in OR and Analytics Network (WORAN), Office for National Statistics, London, UK; [g]University of Kent, Canterbury, UK; [h]Journal of the Operational Research Society, University of Southampton, Southampton, UK; [i]University of Massachusetts, Newton, Massachusetts, USA; [j]University of Warwick, Coventry, UK; [k]Lancaster University, Lancaster, UK; [l]University of Brescia, Brescia, Italy

ABSTRACT

This article comprises a set of commentaries for the paper written by Carroll and Esposito Amideo from different scholars and OR practitioners. The commentaries agree on the impor-

KEYWORDS
Gender Equality; Survey; WISDOM; WORAN

The Future is Bright But Investment is Needed

- **The skillsets of our students are highly sought after.**

- **Our discipline continues to advance methodologies as well as applications. Many of our tools are used by those in different disciplines.**

- **Our members are regularly contacted by the media to inform and comment on current events and issues.**

- **The OR Society, INFORMS, and IFORS have done a great job in terms of advocacy and outreach.**

- **Quite a few of such professional society members are engaged in writing OpEds, etc.**

- **More are being called to advise the government (harkens to the origins of OR).**

The Future is Bright But Investment is Needed

• **The OR discipline arose from applications in practice, including military applications and logistics. Tighter interfaces between academics and practitioners are needed.**

• **There are various initiatives in Europe regarding OR outreach that might be useful to expand.**

• **Grateful that we have begun serious discussions about gender and OR and are celebrating the discipline's greatness!**

Thank You Very Much!

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