

Game Theory, Supply Chains, Labor, and Tariffs: Insights from Variational Inequalities

Professor Anna Nagurney

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

European Meeting on Game Theory (SING21)
University of Naples Federico II, Italy, June 29-July 1, 2026



Acknowledgments

Many thanks to Professor Annamaria Barbagallo, the Chair of this Conference, for the invitation to speak with you!



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

Outline of This Presentation

- **Background and Motivation**
- **Food Supply Chains and Disruptions**
- **International Trade and Policies**
- **Supply Chain Network Model with Labor and Ad Valorem Tariffs**
- **Case Study on the Global Trade of Soybeans**
- **Some Related Recent Research**
- **Making a Positive Impact**

Background and Motivation

I Work on the Modeling of Network Systems



Some of My Books



My Latest Books



For the Love of **Operations Research (OR)** and **Networks**

From my first course at Brown University on the subject to my first projects in industry - working on naval submarines in Newport, Rhode Island, I was drawn to the power of networks, especially when combined with computing.



Off to Grad School for a PhD

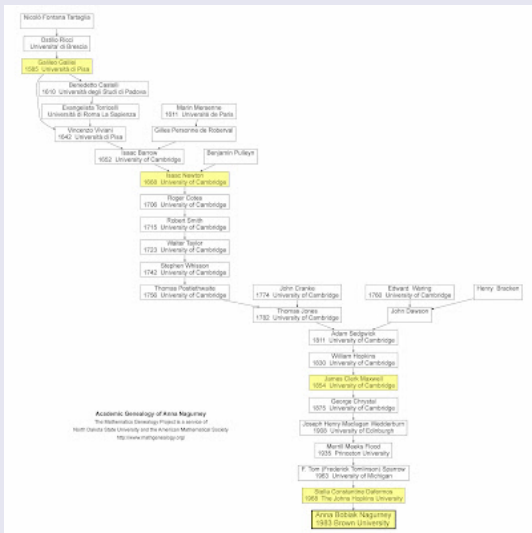
While working in high tech defense consulting I realized that I did not like having a boss. I commuted, ran marathons, and worked full time while taking courses for my Master's at Brown.

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.



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

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



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, wars, and other disasters (both sudden-onset and slow-onset ones).

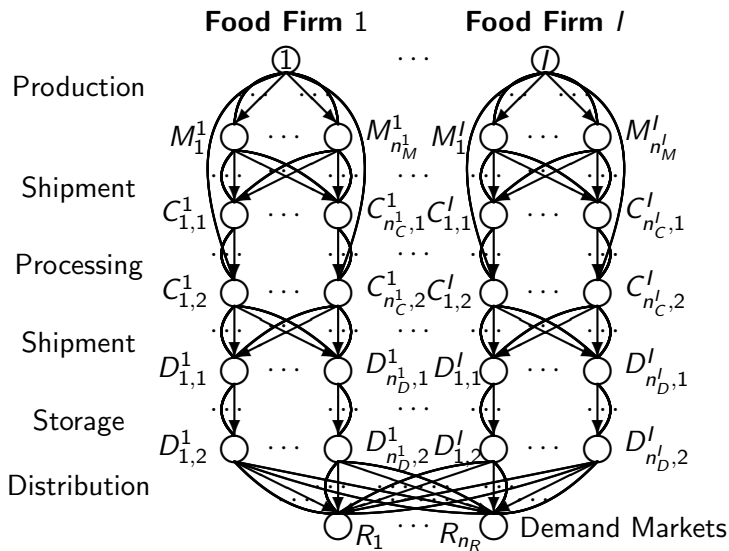


Our fresh produce supply chain network oligopoly model:

- 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.

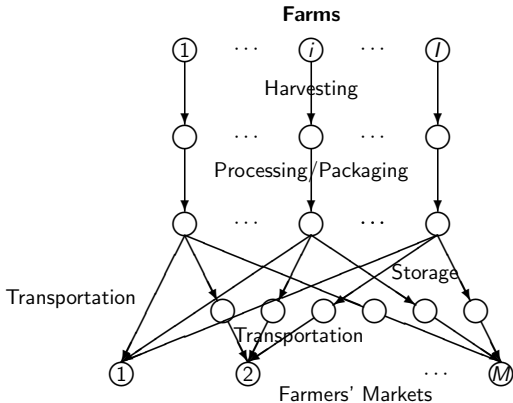
Fresh Produce Food Supply Chains



The Fresh Produce Supply Chain Network Topology

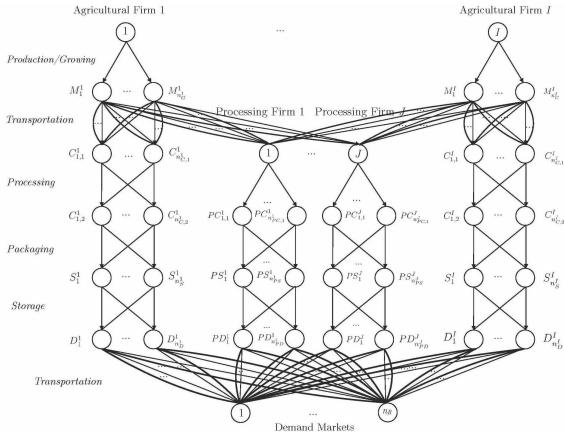
Farmers' Markets and Fresh Produce Supply Chains

- 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



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

QW

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



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

n p r

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.



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: [f](#) [in](#) [t](#)

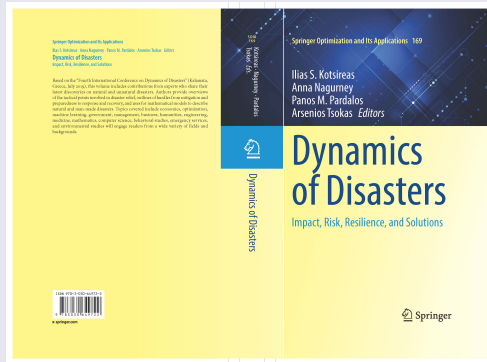
PRINT ARTICLE: [🖨](#)

<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 shelled; 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 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

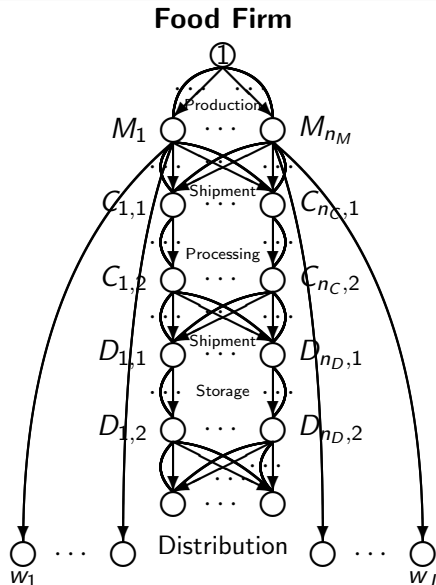


Figure: The Perishable Food Supply Chain Network Topology

Perishable Food Supply Chain Network Model with Labor

- **With lack of availability of labor being one of the drivers of supply chain disruptions**, the model considers labor in all the supply chain network economic activities of production, transportation, processing, storage, and distribution, while retaining perishability.
- **There are bounds on labor availability on each link as well as a productivity factor relating product flow to labor.**
- **Impacts of the reduction of labor (capacities) on supply chain network links** can then be quantitatively evaluated on the perishable product flows, the prices that the consumers pay, and profits of the firm.
- The framework enables a variety of sensitivity analysis exercises.

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 301 (2023) 109805

Contents lists available at ScienceDirect
European Journal of Operational Research

Production, Manufacturing, Transportation and Logistics
Supply chain game theory network modeling under labor constraints:
Application to the Covid-19 pandemic
Anna Nagurney

Journal of Decision and Information Systems, Indiana State University, University of Rochester, Indiana, IN, USA

ARTICLE INFO

ABSTRACT

Keywords:

1. Introduction

The Covid-19 pandemic, officially declared by the World Health Organization on March 11, 2020, has demonstrated dramatically the importance of the supply network in the global economic system. The pandemic requires supply chain networks to be resilient and flexible, able to respond to changes in demand and supply chain disruptions. This paper presents a game theory model for supply chains with labor constraints, under three different sets of constraints, building on our previous work. The model is applied to the supply chain network modeling under labor constraints, under three different sets of constraints, building on our previous work.

European Journal of Operational Research

ELSEVIER

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. Anna Nagurney
Co-ordinating Editor of EJOR

Simon Drew
Publishing Editor of EJOR

Game Theory Supply Chain Network Model with Labor

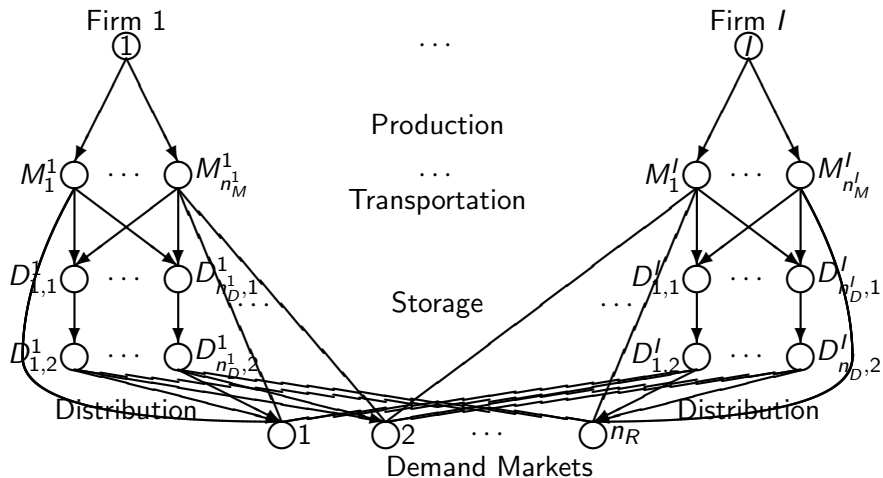


Figure: The Supply Chain Network Topology of the Game Theory Model with Labor

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!

International Trade and Policies

International Trade

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



World Trade Data - Top Exporters and Importers



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 Date to Ancient Times

Ancient Greeks imposed tariffs of 5% on all imports.

In ancient Rome, tariffs—known as portoria—were used mainly for revenue-generation rather than to protect domestic industries. The Roman government levied standard customs duties of 2.5% to 5% on goods moving between provinces, but imposed steep tariffs of up to 25% on imports into the empire such as spices, incense, and silks from Asia.



There are Different Types of Tariffs

- There are unit tariffs, ad valorem tariffs, and tariff rate quotas.
- 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.



Some History of the US and Tariffs

The Tariff of 1789, signed by President George Washington, was one of the first laws passed by the new federal government, was as much about protection as it was about raising money. The tariff imposed duties on a wide range of imported goods and helped to pay down the young nation's war debts. There were both unit tariffs imposed as well as ad valorem tariffs.

- **An ad valorem tariff** of 5% to 15% was imposed on most imported goods.
- **A unit tariff** was imposed on over 30 commodities including: coffee, tea, distilled spirits, cheese, cocoa, and molasses.

Tariffs Are Now 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 **trade wars**.

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. *Uesato/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.

Tariffs Are Now Regularly in the News!

Canada Mexico United States

Trump's Proposed 25% Tariff on Canada and Mexico: Potential Impacts on Agriculture and Trade

By Jim Koels - January 23, 2025



NEWS

Shipping companies warn of delays and new charges from Trump's China tariffs



Temu, Shein, and Amazon Haul are about to get wrecked

/ Delays, taxes, & more
- shipping from just got more co

What might be the impact on agriculture of tariffs on Canadian and Mexican imports?

// BLOG // WHAT MIGHT BE THE IMPACT ON AGRICULTURE OF TARIFFS ON CANADIAN AND MEXICAN IMPORTS?

Tariffs on Canadian and Mexican Imports: The Impact on Agriculture

It should come as no surprise that Mexico and Canada are the top-two US agricultural export markets

PUBLISHED ON JANUARY 29, 2025

America's favorite beer, avocados, gas and cheap stuff from Temu will get more expensive as economists warn of Trump tariffs impact

By Rocky Reyes
Published Feb. 2, 2025, 6:29 p.m. ET

1.9K Comments

New Tariffs That Start Tomorrow Could Affect Farmers and Food Prices

The Trump administration will impose a 25 percent tariff on imports from Canada and Mexico, the U.S.' first and third largest suppliers of agricultural products.

BY USA HELD • JANUARY 31, 2025

Trump's tariffs will hurt UK wherever they're imposed, says Bank

A global trade war would hit growth even if Britain is not a 'direct recipient' of the US president's levies on imports, the Bank of England governor says

NEW

LOCAL NEWS

Colorado agriculture producers brace for tariff impacts



By Chris Young
February 3, 2025, 7:02 AM MST | 286 Colorado



President Donald Trump, on April 2, 2025, proclaimed “Liberation Day” in the White House Rose Garden, announcing a unilateral 10% tariff on almost all foreign imports, rising up to 50% for many countries. He invoked the International Emergency Economic Powers Act (IEEPA).

- The effective tariff rate in the US briefly topped 20%. Even after falling to 10.5% **it is at its highest since the 1940s.**

- **Between May and December 2025, real imports from China were over 40% lower than the same months in 2024.**

The use of “real” implies that the figures are adjusted for price changes (inflation), showing a true, sharp reduction in physical volume of goods, not just a fluctuation in prices.

The IEEPA tariffs were found to be illegal by the US Supreme Court on February 20, 2026.

Over \$160 billion in such tariffs had been collected.

Now the tariff rate on products from the European Union, including Italy to the United States is 15%.

The current US tariff rate on steel and aluminum imports from the EU is 50%. For cars and trucks, the US tariff rate is 25% following an escalation of trade tensions.

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

This is challenging but also highly relevant research!

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.



The model is a game theory one with tariff rate quotas and the numerical case study is on avocados.

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.



The model is a spatial price equilibrium one with tariff rate quotas and the numerical case study is on the dairy industry.

A. Nagurney, M. Salarpour, and J. Dong, “Modeling of Covid-19 Trade Measures on Essential Products: A Multiproduct, Multicountry Spatial Price Equilibrium Framework,” *International Transactions in Operational Research* 29(1) (2022), pp 226-258.



The model is a spatial price equilibrium one with unit tariffs, quotas, price floors and ceilings. The case study is on PPEs.

Supply Chain Network Model with Labor and Ad Valorem Tariffs

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.



Impacts of Tariffs in Supply Chains on Labor

A. Nagurney and S. Samadi, “Ad Valorem Tariffs in Global Supply Chain Networks and Impacts on Labor,” *Journal of the Operational Research Society* (2025),
<https://doi.org/10.1080/01605682.2025.2592758>.



The model is a game theory one with ad valorem tariffs and the numerical case study is on soybeans.

Table: Notation for the Global Supply Chain Network Model with Tariffs

Variables	Definition
s_j^i	nonnegative production output (supply) of firm i at its production site j ; $j = 1, \dots, n_i$. Group outputs for $i = 1, \dots, I$, into vector $s^i \in R_+^{n_i}$ and all such vectors into $s \in R_+^{\sum_{i=1}^I n_i}$.
Q_{jk}^i	nonnegative amount of firm i 's product produced at its site j and shipped to demand market k . The $\{Q_{jk}^i\}$ elements for all j and k are grouped into vector $Q^i \in R_+^{n_i \circ}$ and Q^i ; $i = 1, \dots, I$, into $Q \in R_+^{\sum_{i=1}^I n_i \circ}$.
d_k^i	demand for firm i 's product at demand market k . Group demands for firm i 's product for $i = 1, \dots, I$, into vector $d^i \in R_+^o$ and then group demands for all i into $d \in R_+^{lo}$.
l_j^i	labor (in hours) available at firm i 's production site j ; $i = 1, \dots, I$; $j = 1, \dots, n_i$.
l_{jk}^i	labor (in hours) available for shipping firm i 's product for $i = 1, \dots, I$ from its production site $j = 1, \dots, n_i$ to market k ; $k = 1, \dots, o$.

Table: Notation for the Global Supply Chain Network Model with Tariffs

Functions	Definition
$f_j^i(s)$	production cost at firm i 's site j .
$\hat{c}_{jk}^i(Q)$	total transportation cost associated with shipping firm i 's product, produced at site j , to demand market k .
$\rho_k^i(d)$	demand price function for firm i 's product at demand market k .

Table: Notation for the Global Supply Chain Network Model with Tariffs

Parameters	Definition
w_j^i	hourly wage at firm i 's production site j .
w_{jk}^i	hourly wage for shipping firm i 's product from its production site j to demand market k .
β_j^i	positive factor relating inputs of labor at firm i 's production site j to the amount of product produced there.
β_{jk}^i	positive factor relating inputs of labor to shipment volume of firm i 's product from its site j to market k .
\bar{l}_j^i	upper bound on labor hours of availability at production site j of firm i .
\bar{l}_{jk}^i	upper bound on labor hours of availability for shipment of firm i 's product produced at its site j to market k .
τ_{jk}^i	ad valorem tariff rate between country that production site j of firm i is in and country of market k

Conservation of Flow Equations

The production output at firm i 's site j , s_j^i , is equal to the total shipments of firm i 's product to all the demand markets; that is:

$$s_j^i = \sum_{k=1}^o Q_{jk}^i, \quad i = 1, \dots, l; j = 1, \dots, n_i, \quad (1)$$

whereas the demand for firm i 's product at demand market k , d_k^i , must be satisfied by the firm's product shipments from all the firm's production sites to each demand market; hence:

$$d_k^i = \sum_{j=1}^{n_i} Q_{jk}^i, \quad i = 1, \dots, l; k = 1, \dots, o. \quad (2)$$

Furthermore, all the product shipments must be nonnegative:

$$Q_{jk}^i \geq 0, \quad i = 1, \dots, l; j = 1, \dots, n_i; k = 1, \dots, o. \quad (3)$$

Relationship Between Labor and Productivity

Using an approach as in Nagurney (2023a, b), relating labor to production outputs, as in economics, we have that the relationships, under the assumption of linearity between product outputs and labor, are at the production sites, and in transportation, respectively, as follows:

$$s_j^i = \beta_j^i l_j^i, \quad i = 1, \dots, l; j = 1, \dots, n_i, \quad (4)$$

and

$$Q_{jk}^i = \beta_{jk}^i l_{jk}^i, \quad i = 1, \dots, l; j = 1, \dots, n_i; k = 1, \dots, o. \quad (5)$$

Also, the labor capacities cannot be exceeded, and the labor hours are nonnegative, so that

$$0 \leq l_j^i \leq \bar{l}_j^i, \quad i = 1, \dots, l; j = 1, \dots, n_i \quad (6)$$

and

$$0 \leq l_{jk}^i \leq \bar{l}_{jk}^i, \quad i = 1, \dots, l; j = 1, \dots, n_i; k = 1, \dots, o. \quad (7)$$

Optimization Problems of the Competing Firms

Each firm i ; $i = 1, \dots, I$, seeks to maximize its utility, U^i , consisting of its net revenue, subject to its constraints. Therefore, the optimization problem faced by each firm i ; $i = 1, \dots, I$, is given by:

$$\begin{aligned} \text{Maximize } U^i = & \sum_{j=1}^{n_i} \sum_{k=1}^o \frac{\rho_k^i(d) Q_{jk}^i}{(1 + \tau_{jk}^i)} - \sum_{j=1}^{n_i} f_j^i(s) - \sum_{j=1}^{n_i} \sum_{k=1}^o \hat{c}_{jk}^i(Q) \\ & - \sum_{j=1}^{n_i} w_j^i l_j^i - \sum_{j=1}^{n_i} \sum_{k=1}^o w_{jk}^i l_{jk}^i \end{aligned} \quad (8)$$

subject to: (1) – (7) for i .

The first term in (8) represents the revenue under the ad valorem tariff rate.

Some Reformulations

Because of expression (1), one can redefine the production cost functions (cf. Table 1) in terms of product shipments, thus:

$$\hat{f}_j^i = \hat{f}_j^i(Q) \equiv f_j^i(s), \quad i = 1, \dots, l; j = 1, \dots, n_i. \quad (9)$$

On the demand side, because of (2), one can redefine the demand price functions in terms of product shipments as:

$$\hat{\rho}_k^i = \hat{\rho}_k^i(Q) \equiv \rho_k^i(d), \quad i = 1, \dots, l; k = 1, \dots, o. \quad (10)$$

The production cost and the transportation cost functions are assumed to be convex and continuously differentiable and the demand price functions to be monotonically decreasing in demands, and continuously differentiable.

Some Reformulations

We will also replace the labor variables in the firms' objective functions with their product shipment equivalents. Towards that end, in view of (4) and (1), we have that:

$$\frac{\sum_{k=1}^o Q_{jk}^i}{\beta_j^i} = l_j^i, \quad i = 1, \dots, I; j = 1, \dots, n_i. \quad (11)$$

Also, in view of (5), we have that

$$\frac{Q_{jk}^i}{\beta_{jk}^i} = l_{jk}^i, \quad i = 1, \dots, I; j = 1, \dots, n_i; k = 1, \dots, o. \quad (12)$$

Optimization Problems in Production Shipment Variables

$$\begin{aligned} \text{Maximize } \hat{U}^i(Q) = & \sum_{j=1}^{n_i} \sum_{k=1}^o \frac{\hat{\rho}_k^i(Q) Q_{jk}^i}{(1 + \tau_{jk}^i)} - \sum_{j=1}^{n_i} \hat{f}_j^i(Q) - \sum_{j=1}^{n_i} \sum_{k=1}^o \hat{c}_{jk}^i(Q) \\ & - \sum_{j=1}^{n_i} w_j^i \frac{\sum_{k=1}^o Q_{jk}^i}{\beta_j^i} - \sum_{j=1}^{n_i} \sum_{k=1}^o w_{jk}^i \frac{Q_{jk}^i}{\beta_{jk}^i} \end{aligned} \quad (13)$$

subject to:

$$\frac{\sum_{k=1}^o Q_{jk}^i}{\beta_j^i} \leq \bar{l}_j^i, \quad j = 1, \dots, n_i, \quad (14)$$

$$\frac{Q_{jk}^i}{\beta_{jk}^i} \leq \bar{l}_{jk}^i, \quad j = 1, \dots, n_i; k = 1, \dots, o, \quad (15)$$

$$Q_{jk}^i \geq 0, \quad j = 1, \dots, n_i; k = 1, \dots, o. \quad (16)$$

The utility functions of all the firms are assumed to be concave and continuously differentiable.

We define the feasible sets:

$$K^i \equiv \{Q^i \mid Q^i \text{ satisfies (14) – (16)}\}, \quad i = 1, \dots, I \quad (17a)$$

and

$$K \equiv \prod_{i=1}^I K^i. \quad (17b)$$

Definition 1: Global Supply Chain Network Nash Equilibrium Under Ad Valorem Tariffs

A product shipment pattern $Q^ \in K$ is a global supply chain network Nash Equilibrium under ad valorem tariffs if, for each firm i ; $i = 1, \dots, I$, the following equilibrium condition holds:*

$$\hat{U}^i(Q^{i*}, Q^{-i*}) \geq \hat{U}^i(Q^i, Q^{-i*}), \quad \forall Q^i \in K^i, \quad (18)$$

where $Q^{-i} \equiv (Q^{1*}, \dots, Q^{i-1*}, Q^{i+1*}, \dots, Q^{I*})$.*

According to (18), a Nash Equilibrium is established if no firm, unilaterally, with its selected strategies, can improve upon its utility, given the strategies of the other firms.

Theorem 1: Variational Inequality Formulation of the Global Supply Chain Network Nash Equilibrium Under Ad Valorem Tariffs

A product shipment pattern $Q^* \in K^i$ is a global supply chain network Nash Equilibrium under ad valorem tariffs according to Definition 1 if and only if it satisfies the variational inequality:

$$-\sum_{i=1}^I \sum_{j=1}^{n_i} \sum_{k=1}^o \frac{\partial \hat{U}^i(Q^*)}{\partial Q_{jk}^i} \times (Q_{jk}^i - Q_{jk}^{i*}) \geq 0, \quad \forall Q \in K. \quad (19)$$

Theorem 2: Alternative Variational Inequality Formulations

VI (19) is equivalent to solving: determine

$(Q^*, \lambda^*, \mu^*, \epsilon^*) \in R_+^{\sum_{i=1}^I n_i o} + R_+^{\sum_{i=1}^I n_i} + R_+^{2 \sum_{i=1}^I n_i o}$ such that:

$$\begin{aligned} & \left[- \sum_{i=1}^I \sum_{j=1}^{n_i} \sum_{k=1}^o \frac{\partial \hat{U}^i(Q^*)}{\partial Q_{jk}^i} + \frac{\lambda_j^{i*}}{\beta_j^i} + \frac{\mu_{jk}^{i*}}{\beta_{jk}^i} - \epsilon_{jk}^{i*} \right] \times [Q_{jk}^i - Q_{jk}^{i*}] \\ & + \sum_{i=1}^I \sum_{j=1}^{n_i} \left[\bar{l}_j^i - \frac{\sum_{k=1}^o Q_{jk}^{i*}}{\beta_j^i} \right] \times [\lambda_j^i - \lambda_j^{i*}] \\ & + \sum_{i=1}^I \sum_{j=1}^{n_i} \sum_{k=1}^o \left[\bar{l}_{jk}^i - \frac{Q_{jk}^{i*}}{\beta_{jk}^i} \right] \times [\mu_{jk}^i - \mu_{jk}^{i*}] + \sum_{i=1}^I \sum_{j=1}^{n_i} \sum_{k=1}^o Q_{jk}^{i*} \times [\epsilon_{jk}^i - \epsilon_{jk}^{i*}] \geq 0, \\ & \forall (Q, \lambda, \mu, \epsilon) \in R_+^{\sum_{i=1}^I n_i o + \sum_{i=1}^I n_i + 2 \sum_{i=1}^I n_i o}. \end{aligned} \quad (20)$$

Alternative Variational Inequality Formulations

Or simplified as: determine $(Q^*, \lambda^*, \mu^*) \in R_+^{2 \sum_{i=1}^I n_i o} + R_+^{\sum_{i=1}^I n_i}$ such that:

$$\left[- \sum_{i=1}^I \sum_{j=1}^{n_i} \sum_{k=1}^o \frac{\partial \hat{U}^i(Q^*)}{\partial Q_{jk}^i} + \frac{\lambda_j^{i*}}{\beta_j^i} + \frac{\mu_{jk}^{i*}}{\beta_{jk}^i} \right] \times [Q_{jk}^i - Q_{jk}^{i*}]$$

$$+ \sum_{i=1}^I \sum_{j=1}^{n_i} \left[\bar{l}_j^i - \frac{\sum_{k=1}^o Q_{jk}^{i*}}{\beta_j^i} \right] \times [\lambda_j^i - \lambda_j^{i*}]$$

$$+ \sum_{i=1}^I \sum_{j=1}^{n_i} \sum_{k=1}^o \left[\bar{l}_{jk}^i - \frac{Q_{jk}^{i*}}{\beta_{jk}^i} \right] \times [\mu_{jk}^i - \mu_{jk}^{i*}] \geq 0,$$

$$\forall (Q, \lambda, \mu) \in R_+^{2 \sum_{i=1}^I n_i o + \sum_{i=1}^I n_i}. \quad (21)$$

Case Study on the Global Trade of Soybeans

Numerical Examples: Soybeans

- Soybeans are a leading agricultural commodity in global trade, widely used in livestock feed, plant-based foods, and biofuels, with the market valued at USD **169.65** billion in 2024 and projected to reach USD **255.39** billion by 2033.
- **Global soybean trade is highly concentrated, with Brazil, the United States, and Argentina as leading exporters and China as the dominant importer, making the market particularly sensitive to tariff policies such as those observed during the 2018 US–China trade conflict.**



Network Topology

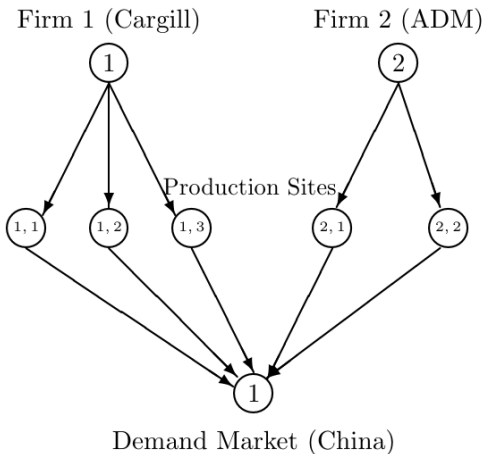


Figure: The Soybean Supply Chain Network Topology for Examples 1, 2, 3, and 4

Example 1: No Ad Valorem Tariffs - Data

- Two firms representing major **US** soybean exporters (stylized versions of Cargill and ADM). Firm 1 operates three production sites (**US, Brazil, Argentina**), while Firm 2 operates two (**US, Brazil**).
- The single demand market represents **China**, the world's largest soybean importer.
- Labor wages differ by country: highest in the **US** and lower in **Brazil** and **Argentina**.
- Ad valorem tariffs are zero: $\tau_{jk}^i = 0$.
- Labor productivity parameters and upper bounds:

$$\beta_j^i = 0.7, \forall i, j, \quad \beta_{jk}^i = 0.7, \forall i, j, k,$$

$$\bar{l}_{jk}^i = 3 \times 10^7, \forall i, j, k,$$

$$\bar{l}_2^1 = \bar{l}_2^2 = 3 \times 10^7, \quad \bar{l}_1^1 = \bar{l}_3^1 = \bar{l}_1^2 = 2 \times 10^7.$$

Example 1: No Ad Valorem Tariffs - Functions

Production Costs

$$\begin{aligned}\hat{f}_1^1(Q) &= 10^{-5}Q_{11}^1{}^2 + 90, & \hat{f}_2^1(Q) &= 4.3 \times 10^{-6}Q_{21}^1{}^2 + 80, \\ \hat{f}_3^1(Q) &= 7.3 \times 10^{-5}Q_{31}^1{}^2 + 100, & \hat{f}_1^2(Q) &= 1.8 \times 10^{-5}Q_{11}^2{}^2 + 90, \\ & & \hat{f}_2^2(Q) &= 9 \times 10^{-6}Q_{21}^2{}^2 + 80.\end{aligned}$$

Transportation Costs

$$\begin{aligned}\hat{c}_{11}^1(Q) &= 2 \times 10^{-5}Q_{11}^1{}^2 + 40, & \hat{c}_{21}^1(Q) &= 5 \times 10^{-6}Q_{21}^1{}^2 + 30, \\ \hat{c}_{31}^1(Q) &= 6 \times 10^{-5}Q_{31}^1{}^2 + 45, & \hat{c}_{11}^2(Q) &= 10^{-5}Q_{11}^2{}^2 + 30, \\ & & \hat{c}_{21}^2(Q) &= 4 \times 10^{-6}Q_{21}^2{}^2 + 15.\end{aligned}$$

Demand Prices

$$\begin{aligned}\rho_1^1(d) &= -1.8 \times 10^{-5}d_1^1 - 10^{-5}d_1^2 + 950, \\ \rho_1^2(d) &= -10^{-5}d_1^1 - 2.5 \times 10^{-5}d_1^2 + 1050.\end{aligned}$$

Discussion of Results: Example 1

- Exports from Brazilian production sites exceed those from US sites, consistent with observed global soybean trade patterns and the real-world trade shares of major firms such as Cargill and ADM.
- Labor allocation follows production scale, with the largest number of workers employed at Brazilian production sites.
- Demand prices in China are \$531.16 per ton for Firm 1 and \$569.77 per ton for Firm 2, both broadly consistent with observed soybean import price of \$463.
- Firm 1 earns higher profits due to its larger production scale, and all Lagrange multipliers associated with labor constraints are zero, indicating that no labor constraints bind at equilibrium.

Example 2: China's Retaliatory Ad Valorem Tariff on US Soybean Exports

- In Example 2, the data are the same as in Example 1 except that we now examine the impact of a newly imposed **25% ad valorem tariff by China on US soybean imports**, announced in April 2025 in direct response to US tariff measures earlier that month.
- The supply chain network structure remains as in Example 1, but we incorporate an ad valorem tariff rate on shipments from US production sites of both firms:

$$\tau_{11}^1 = \tau_{11}^2 = 0.25.$$

Discussion of Results: Example 2

- A 25% Chinese tariff rate **reduces the competitiveness of US soybean exports, causing shipments from US sites to decline and shifting production toward Brazil and Argentina.**
- For Firm 1, exports from the US site drop by 22.26%, while shipments from the US site for Firm 2 decline by 20.44%.
- **Demand prices in China increase as total soybean supply declines, reaching \$536.62 and \$577.10 per ton for the two firms.**
- Labor hours fall at US production sites and on transportation routes but rise in Brazil and Argentina.
- **Profits decline for both firms, by 3.64% for Firm 1 and by 5.76% for Firm 2, despite the reallocation of production.**
- All Lagrange multipliers remain zero in this example.

Example 3: Immigration Policy and its Impact on Available Labor at the US Production Sites

- Example 3 has the same data as that in Example 1, except that we now examine the impact of the current **farm labor shortage in the US due to increased immigration enforcement**.
- In 2025, intensified immigration enforcement and the failure to renew working authorizations led to an estimated **70%** of the agricultural workforce in key regions, especially California, stopping work.
- To simulate the labor shortage, we reduce the available labor hours at both firms' US production sites to $\bar{l}_1^1 = \bar{l}_1^2 = 2 \times 10^6$ hours.

Discussion of Results: Example 3

- **Reduced labor availability at US production sites significantly disrupts soybean output for both firms.**
- **US shipments decline sharply:** by 54.32% for Firm 1 and 59.95% for Firm 2, with labor constraints binding at the US sites.
- **Positive Lagrange multipliers ($\lambda_1^{1*} = 85.10$, $\lambda_1^{2*} = 108.28$) indicate that the labor upper bounds are binding.**
- **Both firms reallocate production towards Brazil and Argentina**, increasing shipments and labor usage at these sites and their associated transportation routes.
- Demand declines slightly while demand prices increase to \$545.31 and \$590.51 per ton.
- **Profits change, but modestly, due to international production reallocation.**

Example 4: Combined Impact of Ad Valorem Tariffs Imposed on US and Brazilian Drought-Induced Production Cost Increases

- Example 4 has the same data as Example 1, except we consider two shocks:
 - China imposes a **25% ad valorem tariff rate** on US soybean imports:

$$\tau_{11}^1 = \tau_{11}^2 = 0.25.$$

- **Drought** conditions in Brazil **increase production costs** at Brazilian sites:

New Production Cost Functions at Brazilian Sites

$$\hat{f}_2^1(Q) = 7 \times 10^{-6} (Q_{21}^1)^2 + 150, \quad \hat{f}_2^2(Q) = 1.3 \times 10^{-5} (Q_{21}^2)^2 + 150.$$

Discussion of Results: Example 4

- The combined shock of a 25% ad valorem tariff and higher Brazilian production costs reallocates global soybean trade flows.
- US exports increase relative to Example 2 but remain below the Example 1 as firms partially shift production back to the US.
- Brazilian exports decline by 7% at both firms, due to higher production costs, while Argentine shipments increase by 19.06% relative to Example 1.
- Labor allocation follows the same pattern: declining in Brazil, increasing in Argentina, with US labor higher than in Example 2 and lower than Example 1.
- Demand prices reach their highest levels, \$557.20 and \$600.36, while demands and profits fall to their lowest levels.
- All Lagrange multipliers remain zero.

Results - Equilibrium Product Flows and Labor Hours at the Production Sites and Transportation Routes

	Example 1	Example 2	Example 3	Example 4
Q_{11}^{1*}	3,065,167.00	2,382,688.56	1,400,000.00	2,850,274.69
Q_{21}^{1*}	12,268,105.34	12,736,900.30	13,433,546.57	11,332,297.71
Q_{31}^{1*}	863,239.02	896,019.96	944,735.71	1,027,857.05
Q_{11}^{2*}	3,496,410.27	2,781,649.05	1,400,000.00	3,331,122.34
Q_{21}^{2*}	9,234,026.64	9,728,068.38	10,668,295.98	8,570,370.78
l_{11}^{1*}	4,378,810.01	3,403,840.80	2,000,000.00	4,071,820.99
l_{21}^{1*}	17,525,864.77	18,195,571.86	19,190,780.81	16,188,996.73
l_{31}^{1*}	1,233,198.61	1,280,028.51	1,349,622.44	1,468,367.22
l_{11}^{2*}	4,994,871.82	3,973,784.35	2,000,000.00	4,758,746.20
l_{21}^{2*}	13,191,466.63	13,897,240.55	15,240,422.83	12,243,386.84
l_1^{1*}	4,378,810.01	3,403,840.80	2,000,000.00	4,071,820.99
l_2^{1*}	17,525,864.77	18,195,571.86	19,190,780.81	16,188,996.73
l_3^{1*}	1,233,198.61	1,280,028.51	1,349,622.44	1,468,367.22
l_1^{2*}	4,994,871.82	3,973,784.35	2,000,000.00	4,758,746.20
l_2^{2*}	13,191,466.63	13,897,240.55	15,240,422.83	12,243,386.84

Results - Demand Prices, Demands, and Profits

	Example 1	Example 2	Example 3	Example 4
d_1^{1*}	16,196,511.37	16,015,608.82	15,778,282.28	15,210,429.45
d_1^{2*}	12,730,436.91	12,509,717.43	12,068,295.98	11,901,493.13
$\hat{\rho}_1^1$	531.16	536.62	545.31	557.20
$\hat{\rho}_1^2$	569.77	577.10	590.51	600.36
\hat{U}^1	6,502,623,987.76	6,265,508,717.39	6,507,263,407.57	5,933,698,880.38
\hat{U}^2	5,502,368,550.04	5,185,244,846.39	5,392,080,170.32	4,902,279,307.20

What Our Research Has Shown

Whether in the context of supply chain networks under oligopolistic (imperfect) competition or perfect competition, our studies reveal that tariffs:

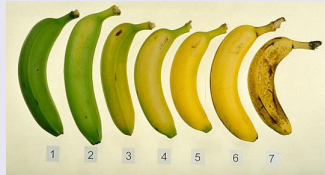
- increase prices for consumers;
- reduce the volume of the product;
- decrease consumer welfare;
- reduce profits for producers (unless new markets and production sites can be identified), and
- they can result in the same impacts as that of quotas.

Tariffs can, however, offer some protection to domestic producers but one has to evaluate whether this will happen quantitatively through OR models.

Some Related Recent Research

Some of Our Latest Research

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.



The ongoing conflict between the United States, Israel, and Iran has led to the closure of the Strait of Hormuz, resulting in a global shipping standstill. Among the casualties is the Indian produce industry, which, as of March 9, 2026, had about 1,000 containers of bananas and other produce stuck at the Jawaharlal Nehru Port.

The Research Was Recently Published in EJOR

European Journal of Operational Research 334 (2026) 149–170



Contents lists available at ScienceDirect
European Journal of Operational Research

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



Decision Support

Fresh produce spatial price equilibrium on general networks: Capturing commodity quality deterioration through endogenous transportation time delay functions with capacities

Anna Nagurney^{a,*}, Samirasadat Samadi^a, Deniz Besik^b

^a Department of Operations and Information Management, Isenberg School of Management, University of Massachusetts, Amherst, MA 01003, United States of America

^b Adnan School of Business, University of Richmond, Richmond, VA 23072, United States of America

ARTICLE INFO

Keywords:
Networks
Equilibrium
Transportation
Variational inequalities
Fresh produce quality

ABSTRACT

Fresh produce is vital to global food security but is highly vulnerable to transportation delays and capacity disruptions, as in critical links such as the Panama Canal. This paper develops a commodity fresh produce trade equilibrium model under quality deterioration on a general network, allowing for multiple transportation links on a path between supply and demand markets. We extend the Bureau of Public Roads (BPR) congestion function to endogenous time delay as a function of all commodity shipments on a link, by including link upper bounds in time delay functions, we capture how upper bounds impact transportation time and fresh produce quality. The spatial price equilibrium conditions are formulated as a variational inequality problem. We also propose commodity quality trade network performance measures, supply-based, demand-based, and network-based, that can be applied for an individual commodity or across all commodities. We apply the model to bananas, a globally popular and nutritious fruit, and to coffee from Ecuador and Costa Rica in the European Union, the United States, and Russia, focusing on drought-driven congestion at the Panama Canal. Numerical examples, whose solutions are computed using the modified projection method, show that reductions in transportation link upper bounds and increased free-flow transportation times significantly lower banana shipments, degrade their quality, and shift prices at both supply and demand markets. We include benchmark comparisons with linear congestion and no-congestion specifications to explicitly quantify how nonlinear congestion modeling alters equilibrium flows, prices, transportation times, and quality deterioration. These comparisons reveal that linear and no-congestion specifications can misrepresent congestion effects, particularly when flows operate at moderate-to-high utilization levels. The results align closely with real-world data on banana prices, transportation costs, and export volumes, reinforcing the model's practical relevance. Our model provides decision-makers with essential insights on the impacts of congestion and increasing transportation times on fresh produce trade and its quality, along with the performance of the trade network.

1. Introduction

Fresh produce, in the form of fresh fruits and vegetables, is essential for the health and well-being of societies. Fresh fruits and vegetables are produced by farmers in different parts of the globe, and then transported to demand markets for purchase by consumers. Such fresh produce trade networks help to support food security and provide consumers with nutrition. The global revenue in 2022 from fresh vegetables was expected to be 691.20 billion US dollars and 622.80 billion US dollars for fresh fruit with the expected volume growth for 2022 being 3.2% and 2.9%, respectively (International Fresh Produce Association, 2023). Furthermore, although the World Health

Organization recommends 400 g of fruits and vegetables per day per person, world production is at 390 g per person per day, with world consumption at only 267 per person per day.

Fresh produce is perishable, and, hence, even under the best conditions, its quality deteriorates over time (see Yu and Nagurney (2013)). Major challenges now associated with transportation include, among others: congestion on roads and at airports, reduced capacity of major links such as the Panama Canal, because of a drought, as well as of the Red Sea and the Suez Canal, because of war-made attacks, plus maritime route capacity reductions on the Black Sea due to Russia's full-scale invasion of Ukraine and Russia's pulling out of the Black Sea

* Corresponding author.

E-mail address: nagurney@isensberg.umass.edu (A. Nagurney).

<https://doi.org/10.1016/j.ejor.2026.04.025>

Received 21 January 2025; Accepted 18 April 2026

Available online 27 April 2026

0377-2217/© 2026 Elsevier B.V. All rights are reserved, including those for text and data mining, AI training, and similar technologies.



Fresh Produce Quality Deterioration

- Fresh produce is perishable, and, hence, even under the best conditions, **its quality deteriorates over time.**
- Major challenges associated with transportation include:
 - **Congestion** on roads and at seaports.
 - Reduced capacity of major links such as the **Panama Canal**, because of a drought.
 - Man-made attacks in the Red Sea, the **Suez Canal** as well as the **Strait of Hormuz**.
 - Maritime route capacity reductions on the Black Sea due to **Russia's full-scale invasion of Ukraine** and **Russia's pulling out of the Black Sea Grain Initiative.**

A Major Shipping Link: The Panama Canal

- Panama Canal Authority decreased the number of daily cargo ship slots from **32 to 24** at the beginning of November 2023, with the number expected to drop to **18** by February 2024.
- Freight service providers that focus on refrigerated products were considering **traveling around South America**, resulting in **a week's delay** in the arrival of the fruit.



Features of the Model

- Each supply–demand pair can be connected via **multiple routes**, each route composed of one or more links, reflecting **multi-modal transport** scenarios.
- Introduces **nonlinear** congestion functions that capture the **time delay** effects of all commodities sharing a link, directly impacting **quality deterioration**, and extend Bureau of Public Road (BPR) functions.
- **Upper bounds** on shipments are embedded within time delay functions, enabling a direct assessment of how capacity constraints affect product quality.
- Proposes innovative **quality trade network performance metrics** (supply-based, demand-based, network-based, and commodity-specific) to evaluate market performance from a quality standpoint.

The Multicommodity Fresh Produce Trade Model

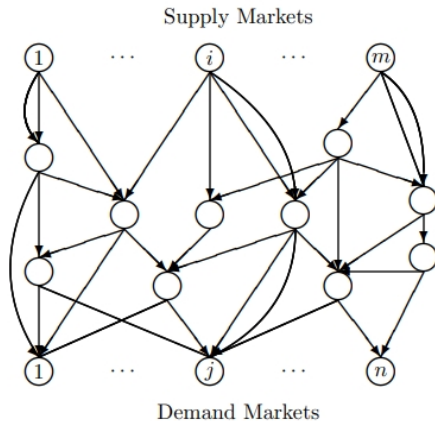


Figure 1: A Trade Network Topology

Expansion of the Bureau of Public Road (BPR) Functions

We let f_a^k denote the flow of commodity k on link a , for all commodities k and all links a .

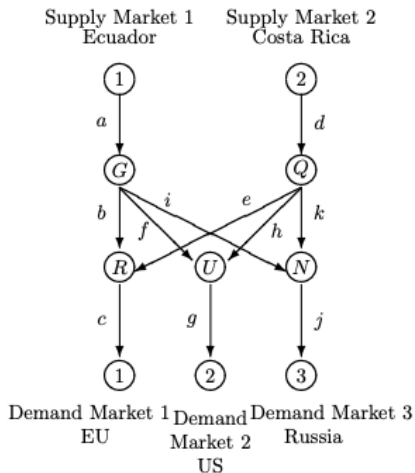
$$t_a = t_a^0 \left(1 + \alpha_a \left(\frac{\sum_{k=1}^K \eta_a^k f_a^k}{u_a} \right)^{\gamma_a} \right), \quad \forall a \in L,$$

η_a^k is a positive parameter for all k and for all a , and α_a is a positive parameter for all a since we assume congestion effects. γ_a represents how the travel time on a link is affected by the commodity flow on the link.

Under the assumption of 0 order quality decay, quality of commodity k on path $p \in P^i$ takes the form:

$$q_p^k = q_i^{0k} - \sum_{a \in p} \kappa_a t_a^0 \left(1 + \alpha_a \left(\frac{\sum_{k=1}^K \eta_a^k f_a^k}{u_a} \right)^{\gamma_a} \right), \quad \forall k, \forall p \in P^i.$$

Case Study on the Banana Trade



- The study underscores **the vulnerability of perishable commodities when critical transit routes are disrupted.**
- **Monitoring flow-dependent transportation times and quality deterioration across individual links is essential for mitigating supply chain risks.**
- The proposed quality performance measures **enable decision-makers to evaluate which markets dominate in fresh produce quality and quantify the overall trade network performance.**
- Future research **could extend the model to include other vital routes (e.g., the Suez Canal), incorporate aspects of uncertainty, exchange rates, and policy instruments such as tariffs.**
- Overall, **the framework offers valuable insights for policymakers and supply chain planners aiming to enhance fresh produce quality and to improve trade network resilience.**

Some Related Recent Research

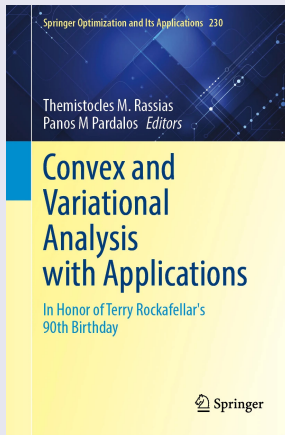
In addition to tariffs and impacts, our recent research has also involved the modeling and calculation of integrated crop and cargo war risk insurance.



The numerical case study is on wheat and corn trade.

Some Related Recent Research

The paper, “Multicommodity Trade, Tariffs, and Rerouting,”
A. Nagurney and S. Samira, in the (2026) book in honor of
Terry Rockafellar.




Making a Positive Impact

THE CONVERSATION
An independent and award-winning source of news, analysis and commentary from academic experts.

Home | 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 11:24am EST



Author
Anna Nagurny
Ph.D., Assistant Professor of Leadership Studies at the University of Massachusetts Lowell

Business & Economics
Anna Nagurny, Ph.D., is an assistant professor of leadership studies at the University of Massachusetts Lowell. She has published articles on leadership and organizational behavior in several journals. She is also a frequent speaker at conferences and seminars on leadership and organizational behavior.

Universities
UMASS AMHERST
University of Massachusetts Amherst
Department of Leadership Studies
100 North College Street
Amherst, MA 01003-0001

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

Chicago Tribune

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

By Anna Nagurny
@annanagurny

ANNOUNCED BY | EDITORIAL ASSISTANT

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

Anna Nagurny, 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 shelter as the aftermath of the Category 4 hurricane, which already has claimed more than 300 inches on the coastline

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 NAGURNY, THE CONVERSATION

Homeland Security News Wire

BIOMETER'S BORDER, IMMIG, BUSINESS CYBERSECURITY
PUBLIC SAFETY PUBLIC HEALTH REGIONAL SCIENCE

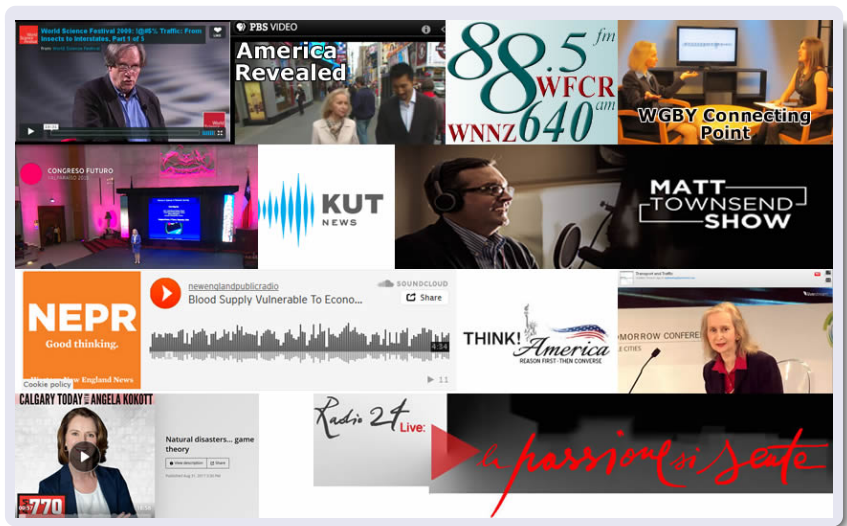
Yale Cyber Leadership Forum - March 30 - April 1, 2017
Expanding the digital frontier with a new course, the Cyber Leadership Forum is a collaboration between Yale and the Center for Cyber Security.

Disaster response
How disaster relief efforts could be improved with game theory
By Anna Nagurny
Published on March 2017

Like | Share | Comment

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

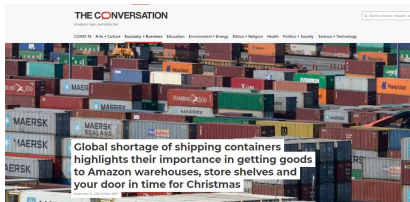
“The Raging Competition for Medical Supplies is not a Game, but Game Theory Can Help.”



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.

Writings After the Full-Scale Invasion



IndustryWeek
INTELLIGENCE | TALENT | TECHNOLOGY & AI | OPERATIONS | LEADERSHIP

After One Year of War, How Is Ukraine Managing?

APR 16, 2023
Signs of economic resilience include a functioning banking system and a thriving IT sector.



The Messenger Opinion.

It's time to break the news.

OPINION

THE VIEWS EXPRESSED BY CONTRIBUTORS ARE THEIR OWN AND NOT THE VIEW OF THE MESSENGER

To Plant or Not to Plant? For Ukrainian Farmers, It's Life or Death

Published 06/11/23 09:30 AM ET | Updated
Anna Nagurney

CHICAGO SUN-TIMES

Ukraine's Students

TO THE EDITOR:

Re "For Children of War, a Time for Play" (news article and photo essay, Aug. 8):

As children, their families and teachers get excited about the new school year throughout the world, it is imperative



Operations Research for the Recovery and Reconstruction of Ukraine

By Anna Nagurney



C6 | THURSDAY, MAY 11, 2023

THE REPUBLICAN MASSLIVE.COM

OPINION

LETTERS TO THE EDITOR

Scholars from Ukraine, UMass find common ground

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.
March 16 at 2:00 p.m.



The war in Ukraine is no longer just a story about a conflict between nations. It's having an immedi...



Anna Nagurney with John Moore

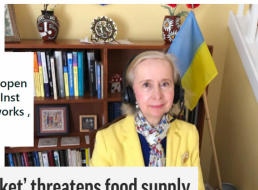


The John Bachelor Show

1/2: #Ukraine: The Kyiv School of Economics is open for business under fire. Paul Gregory @HooverInst @PaulR_Gregory. Anna Nagurney @Supernetworks, University of Massachusetts. Paul Becker, Duke University

'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 Jerry Gross

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

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

Responding to Media Requests on Tariffs

I believe that it is important to respond to media requests on topics that your research can inform, such as that of our work on tariffs and trade.

wbur
From vinegar to vanilla: Trump tariffs leave Massachusetts small businesses in the lurch

Tariff impact is already felt by Western Massachusetts companies

NEWSTALK WHMP

The New York Times
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.

MASS LIVE

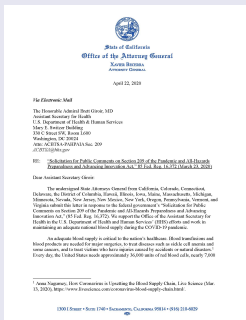
Daily Hampshire Gazette
Dash to the dealership?: Local consumers, car sellers brace for auto tariffs to kick in Wednesday

Dynamics of Decision

Computable mathematical models and associated analyses on tariffs and trade can provide valuable insights (including unexpected ones) for policy-makers and decision-makers.

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.



Xavier Becerra, then CA Attorney General, became the Secretary of Health and Human Services in the US under President Biden and the then Massachusetts Attorney General is now Governor Maura Healy of Massachusetts!

Thank You Very Much!



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