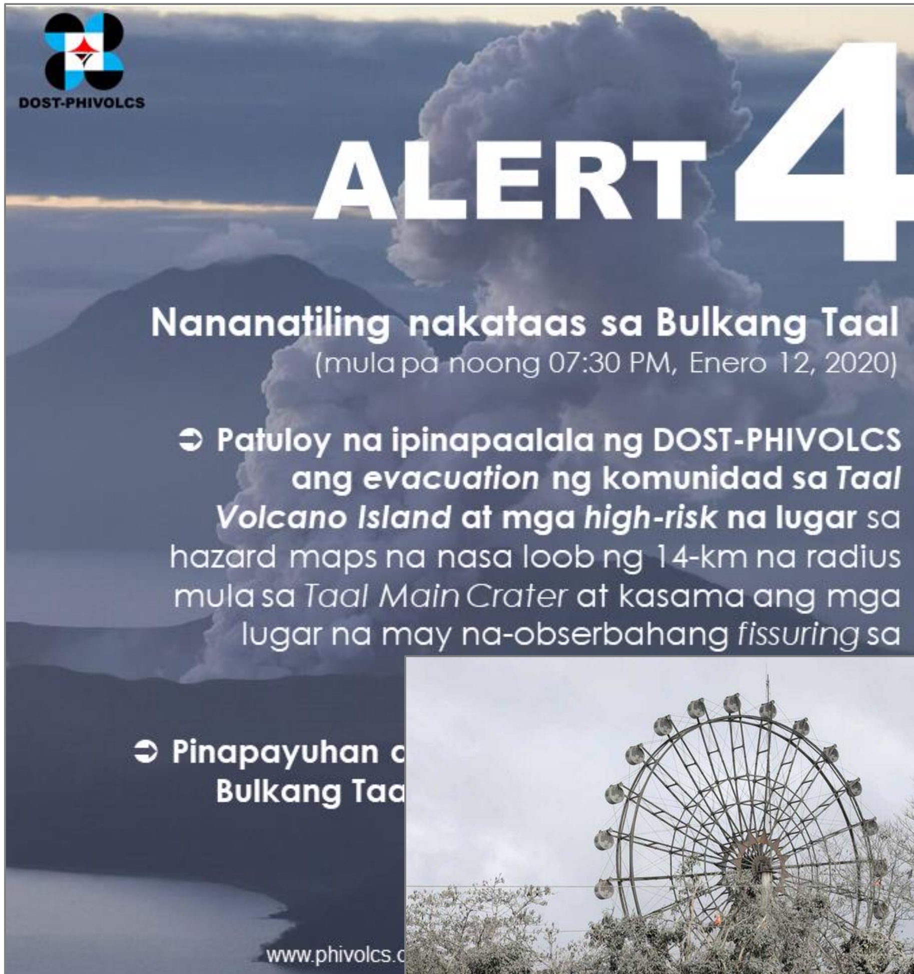
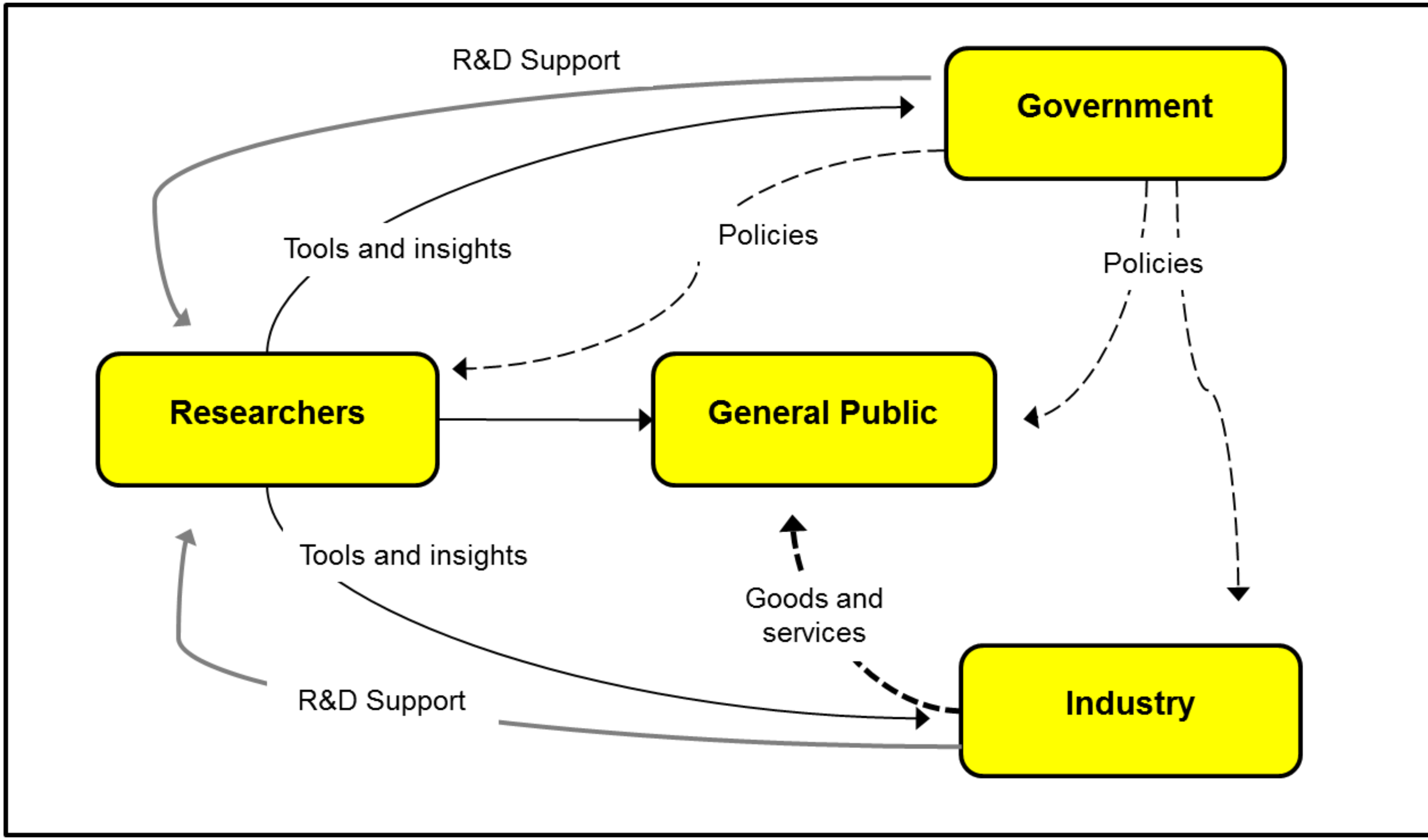
Multi-regional Disaster Risk Analysis for the Philippines

Legazpi Room, KL Serviced Residences

January 24, 2019


DOST-PHIVOLCS
ALERT 4
Nananatiling nakataas sa Bulkang Taal
(mula pa noong 07:30 PM, Enero 12, 2020)
➲ Patuloy na ipinapaalala ng DOST-PHIVOLCS ang *evacuation* ng komunidad sa *Taal Volcano Island* at mga *high-risk* na lugar sa hazard maps na nasa loob ng 14-km na radius mula sa *Taal Main Crater* at kasama ang mga lugar na may na-obserbahang *fissuring* sa
➲ Pinapayuhan
Bulkang Taa
www.phivolcs.

"Big Picture" Rationale for Research

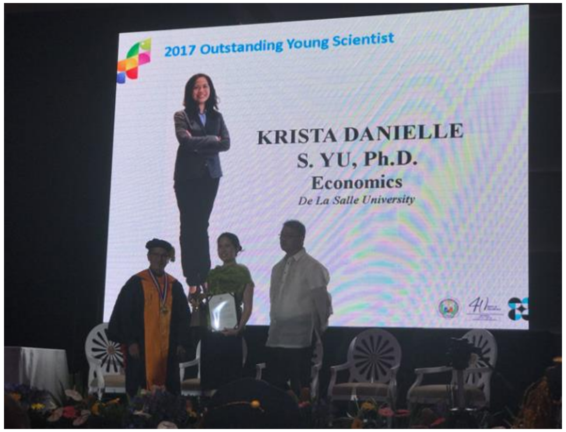


De La Salle University
Manila, Philippines

*"A leading learner-centered and research University bridging faith and scholarship, **attuned to a sustainable Earth**, and in the service of Church and society, especially the poor and marginalized."*

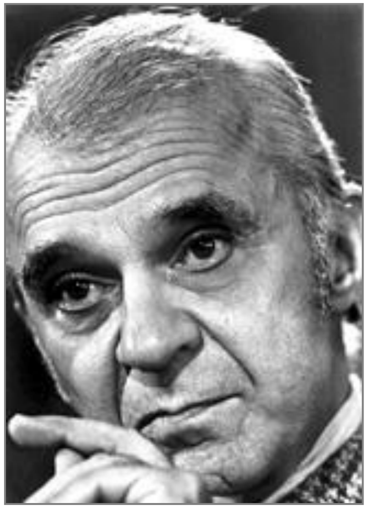
- A private, comprehensive, non-stock/non-profit Catholic university founded in **1911** and granted university status in **1975**
- Ranked **1st among PH HEIs** in number of Scopus-indexed publications in 2019.
- **500%** research output growth in 2010-2019
- THE World Ranking **1001+**
- THE Emerging Economies Ranking **251+**
- THE Asia-Pacific Ranking **201+**
- THE Asian Ranking **251+**
- THE Impact Ranking **301+**
- THE Subject Ranking (Soc. Sci.; Eng. & Tech.) **501+**
- QS World Ranking **801+**
- QS Asian Ranking **155**
- Scimago Institution Ranking **777**

National Academy of Science and Technology (NAST) Award and Grant



- Awarded 2017 NAST Outstanding Young Scientist in the field of Economics
- Received grant for Disaster Risk Assessment Computation Using Leontief Analysis in 2018
- Hosted Research Forum on Economic Systems Modelling for Disaster Risk Assessment (February 26, 2019)
- Trained 2 graduate students

Leontief and Input-Output Analysis



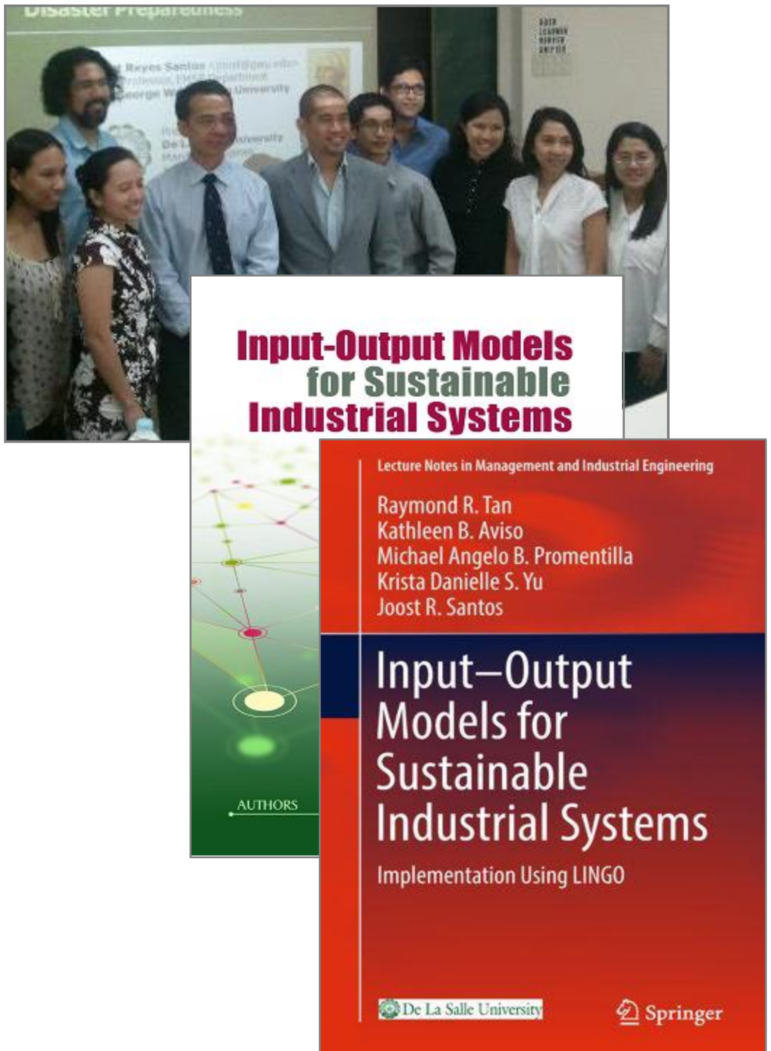
Wassily Leontief received the 1973 *Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel*

"for the development of the input-output method and for its application to important economic problems."

(www.nobel.org)

New from Springer Nature / DLSU

(https://link.springer.com/book/10.1007/978-981-13-1873-3)



A book on IO methodology for industrial sustainability.

Authors:

- ❑ Prof RR Tan (DLSU, PH)
- ❑ Prof KB Aviso (DLSU, PH)
- ❑ Prof MAB Promentilla (DLSU, PH)
- ❑ Dr KDS Yu (DLSU, PH)
- ❑ Dr JR Santos (GWU, USA)

Input-Output Modelling for Disaster Risk Analysis

Prof. Raymond R. Tan, Ph.D.
De La Salle University, Manila, Philippines

About Myself

Career highlights

- Professor of Chemical Engineering and University Fellow
- DLSU Vice-Chancellor for Research and Innovation
- 300+ publications, 6000+ citations and *h*-index = 41 (Scopus)
- Academician, National Academy of Science & Technology of the Philippines (NASTPH)
- BS and MS ChemE, PhD MechE (DLSU)
- Multiple scientific awards from the DOST, CHED, NASTPH, NRCP, PhilAAST, DLSAA, and PAASE
- Co-editor-in-chief of *Process Integration & Optimization for Sustainability* (Springer Nature) and subject editor of *Sustainable Production & Consumption* (IChemE/Elsevier)
- Member of the editorial boards of the journals *Clean Technologies & Environmental Policy* (Springer Nature) and *Int. J. of Supply Chain and Operations Resilience* (Inderscience)
- Co-author of *Process Integration Approaches to Planning Carbon Management Networks* (CRC Press), *Input-Output Models for Sustainable Industrial Systems* (Springer Nature),
- Co-editor of *Recent Advances in Sustainable Process Design and Optimization* (World Scientific) and *Process Design Strategies for Biomass Conversion Systems* (Wiley)

Areas of interest

- Process systems engineering (PSE), process integration (PI), life cycle assessment (LCA), input-output (I-O) modelling, process graph (P-graph)

Outline of Presentation

- Risk analysis and input-output models
- A “toy model” tutorial
- Analysis using low-resolution Philippine data
- Conclusions and further research opportunities

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Risk Analysis

(Kaplan and Garrick, 1981. RA 1:11)

- What can go wrong?
- What is the likelihood?
- What are the consequences?

System connectivity and interdependencies have made rigorous modeling essential for the third question.

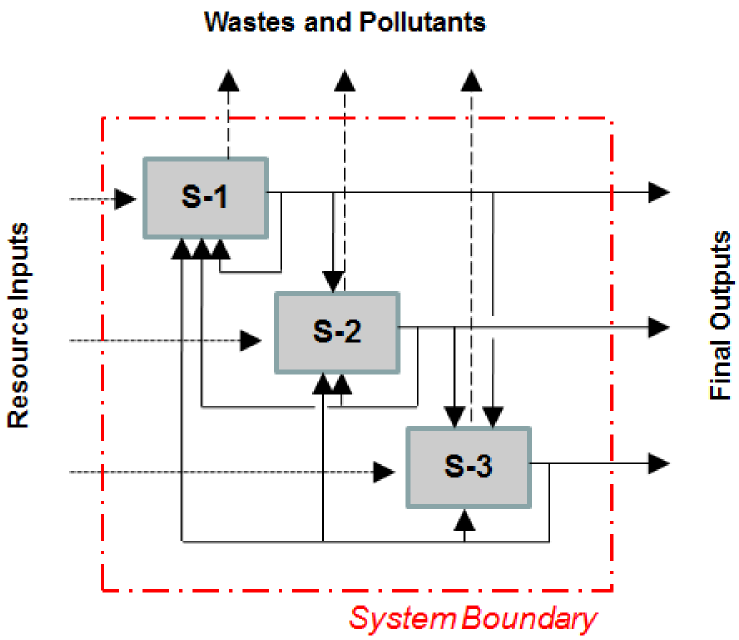
Disruptive Events and Ripple Effects

Triggering Event	Examples of Collateral Damage
Tsunami	➢Job losses due to hotel closures ➢Small businesses go bankrupt
Flu outbreak	➢Labor shortage across multiple sectors ➢Loss of industrial output across multiple sectors
Volcanic eruption	➢Manufacturing plant closures ➢Crop failure ➢Tourism losses
Prolonged drought	➢Crop failure ➢Shutdown of hydroelectric power plants ➢Loss of industrial output ➢Reduced investment ➢Loss of livelihood

Input-Output (IO) Models

(Leontief, 1936. RES 18: 105)

IO analysis was developed by Leontief for the rigorous mathematical analysis of interactions of interconnected economic sectors



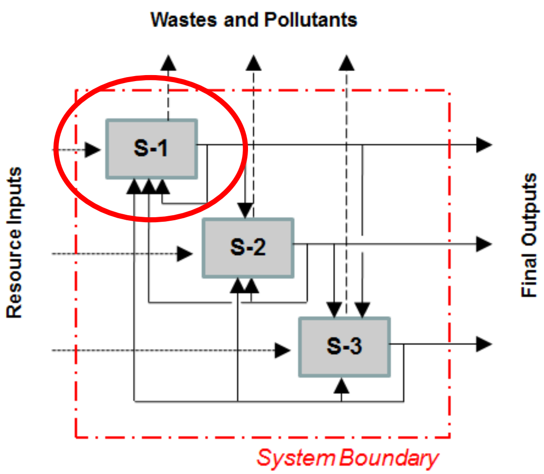
$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\,\mathbf{y}$$

$$\mathbf{E}\,\mathbf{x} = \mathbf{z}$$

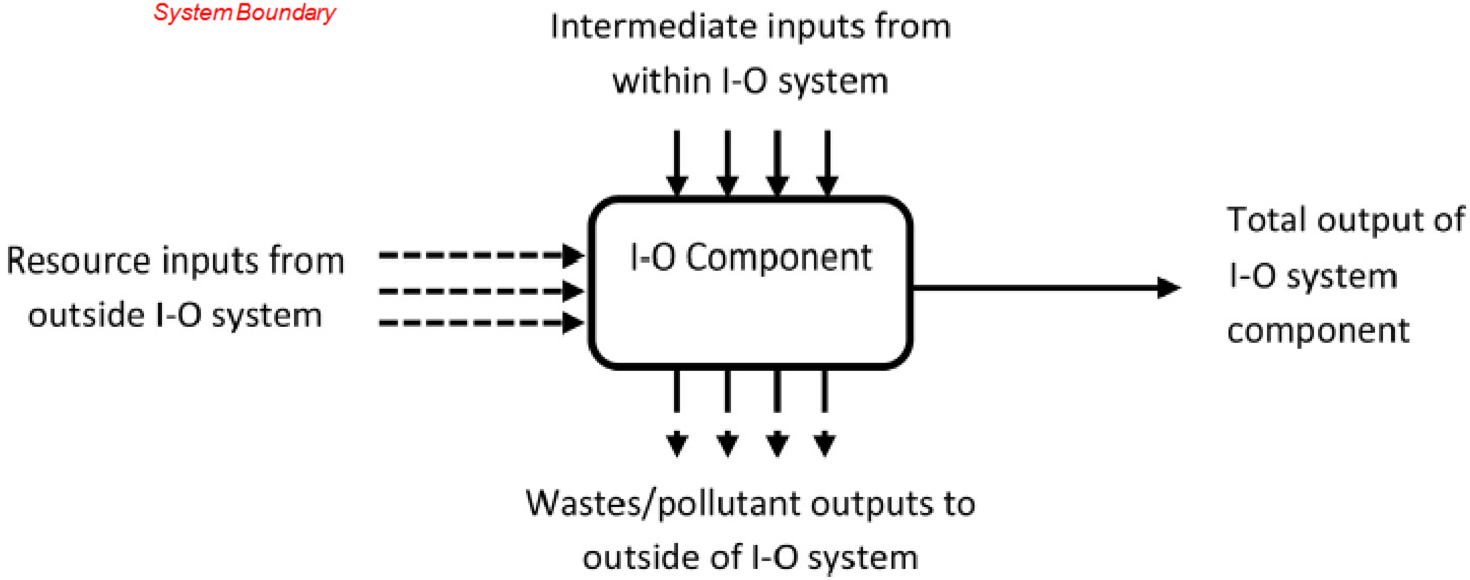
where:

A	=	Technical coefficient matrix
E	=	Environmental coefficient matrix
I	=	Identity matrix
x	=	Total output vector
y	=	Final demand vector
z	=	Environmental vector

Building Blocks of IO Systems



- Assumption of scale invariance results in linear model
- Consistent with other methodologies such as life cycle assessment (LCA)



Sample IO Data (Philippines, 65 Sectors)

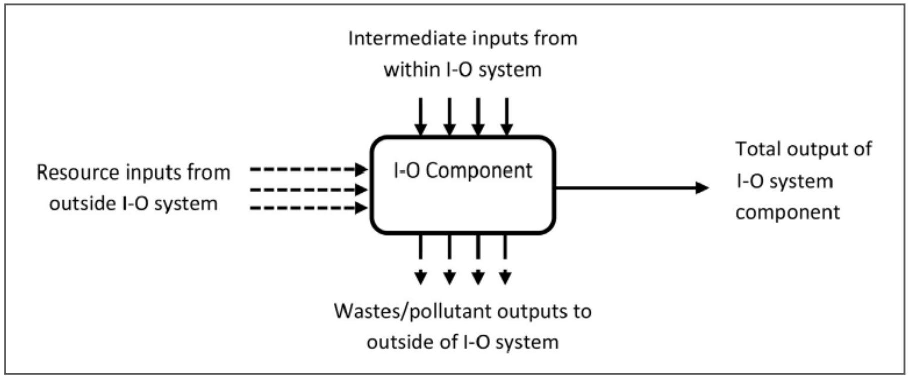
(https://psa.gov.ph/statistics/input-output)

2012 Input-Output Tables of the Philippines

65-Sector Technical Coefficient

Industry Technology Assumption

	Description	1 Palay	2 Corn	3 Coconut	4 Sugarcane	5 Banana	6 Other crops	7 Livestock
1	Palay	0.03979	0.05712	0.00853	0.02515	0.01810	0.01952	0.01145
2	Corn	0.00635	0.01819	0.00653	0.01587	0.00757	0.00679	0.02347
3	Coconut	0.00815	0.04175	0.03026	0.00371	0.00797	0.01047	0.00063
4	Sugarcane	0.00088	0.00428	0.00007	0.00038	0.00078	0.00105	0.00153
5	Banana	0.00104	0.00081	0.00101	0.00229	0.00112	0.00106	0.00316
6	Other crops	0.00222	0.00659	0.00039	0.00090	0.00142	0.00218	0.01437
7	Livestock	0.00235	0.00227	0.00246	0.00731	0.00279	0.00255	0.03616
8	Poultry	0.00128	0.00108	0.00141	0.00424	0.00158	0.00134	0.00367
9	Agricultural activities and services	0.04511	0.04086	0.04805	0.12970	0.05470	0.04707	0.04862
10	Forestry	-	0.00000	-	0.00001	0.00000	0.00002	0.00000
11	Fishery	0.00751	0.00170	0.00120	0.00338	0.00217	0.00620	0.00108
12	Gold mining	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
13	Copper mining	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
14	Chromite mining	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
15	Nickel mining	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001



Inoperability Input-Output Modelling (IIM)

(Haimes and Jiang, 2001. JIS 7: 1; Santos and Haimes. 2004. RA 24: 1437)

LEONTIEF-BASED MODEL OF RISK IN COMPLEX INTERCONNECTED INFRASTRUCTURES

By Yacov Y. Haimes[1] and Pu Jiang[2]

ABSTRACT: Wassily Leontief received the 1973 Nobel Price in Economics for developing what came to be known as the Leontief input-output model of the economy. Leontief's model enables understanding the interconnectedness among the various sectors of an economy and forecasting the effect on one segment of a change in another. A Leontief-based infrastructure input-output model is developed here to enable an accounting of the intraconnectedness within each critical infrastructure as well as the interconnectedness among them. The linear input/output model is then generalized into a generic risk model with the former as the first-order approximation. A preliminary study of the dynamics of risk of inoperability is discussed, using a Leontief-based dynamic model. Several examples are presented to illustrate the theory and its applications.

BACKGROUND

The advancement in information technology has markedly increased the interconnectedness and interdependencies of our critical infrastructures, such as telecommunications, electrical power systems, gas and oil storage and transportation, banking

for generations (Haimes 1999). We know, for example, that the quality and quantity of ground water of unconfined aquifer systems interact with and are functions of the quality and quantity of surface water. Furthermore, the quality and quantity of surface and ground water are functions of the quality of point and nonpoint discharges of treated or untreated efflu-

Risk Analysis, Vol. 24, No. 6, 2004

Modeling the Demand Reduction Input-Output (I-O) Inoperability Due to Terrorism of Interconnected Infrastructures[1]

Joost R. Santos[2*] and Yacov Y. Haimes[2]

Interdependency analysis in the context of this article is a process of assessing and managing risks inherent in a system of interconnected entities (e.g., infrastructures or industry sectors). Invoking the principles of input-output (I-O) and decomposition analysis, the article offers a framework for describing how terrorism-induced perturbations can propagate due to interconnectedness. Data published by the Bureau of Economic Analysis Division of the U.S. Department of Commerce is utilized to present applications to serve as test beds for the proposed framework. Specifically, a case study estimating the economic impact of airline demand perturbations to national-level U.S. sectors is made possible using I-O matrices. A ranking of the affected sectors according to their vulnerability to perturbations originating from a primary sector (e.g., air transportation) can serve as important input to risk management. For example,

- ❑ Haimes and Jiang (2001) defined inoperability as *"the inability of the system to perform its intended function."*
- ❑ Santos and Haimes (2004) interpreted the original definition as fractional economic loss to allow use of IO data.

Inoperability Input-Output Modelling (IIM)

(Haimes and Jiang, 2001. JIS 7: 1; Santos and Haimes. 2004. RA 24: 1437)

$$\boldsymbol{q} = \mathbf{A^*}\boldsymbol{q} + \boldsymbol{c}$$

$$\boldsymbol{q} = (\mathbf{I} - \mathbf{A^*})^{-1}\,\boldsymbol{c}$$

$$\boldsymbol{q} = (\mathbf{I} + \mathbf{A^*} + \mathbf{A^*}^{2} + \mathbf{A^*}^{3}\ldots)\,\boldsymbol{c}$$

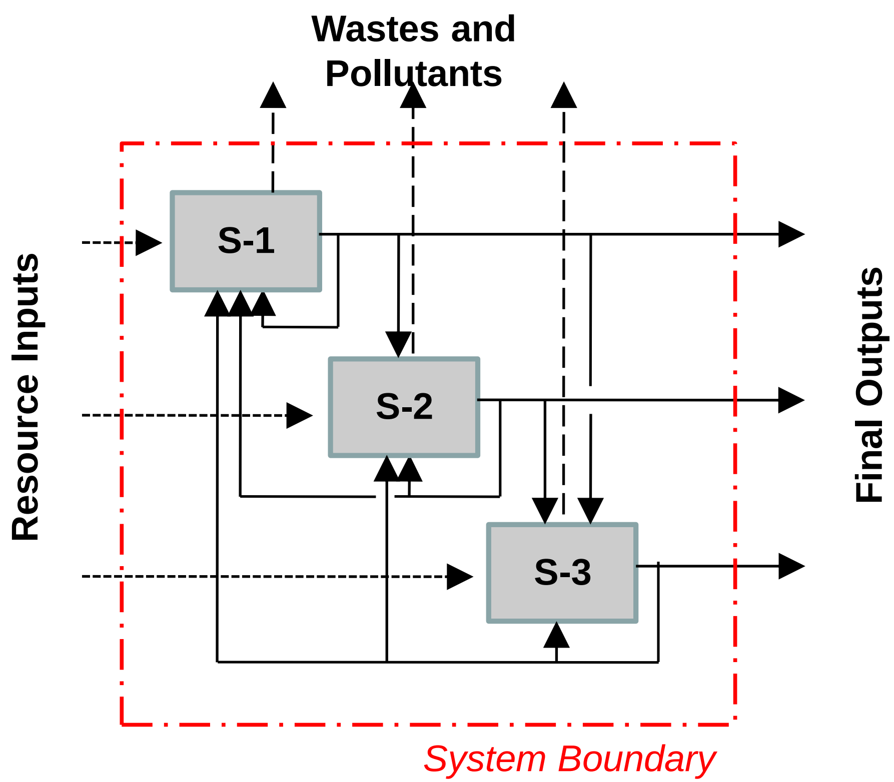
where:

A* = interdependency matrix

c = initial inoperability vector

I = identity matrix

q = final inoperability vector



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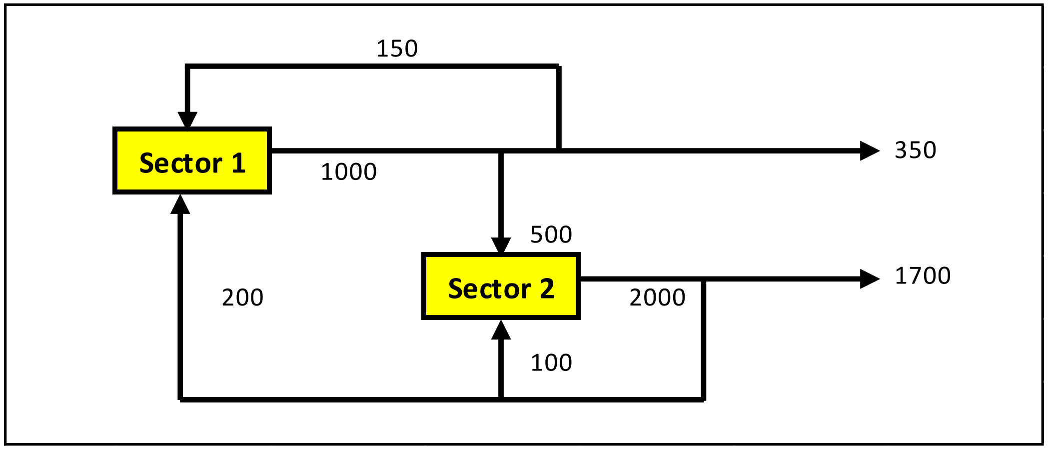
Toy Model of a Two-Sector Economy

(Miller and Blair, 2009)



	Sector 1	Sector 2	Final Demand (y)	Total Output (x)
Sector 1	150	500	350	1000
Sector 2	200	100	1700	2000

Toy Model of a Two-Sector Economy

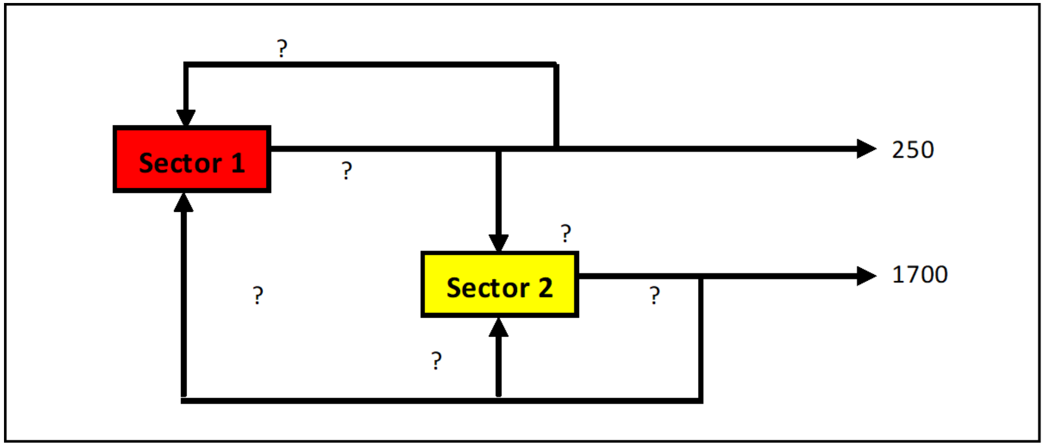
(Miller and Blair, 2009)

	Sector 1	Sector 2	Final Demand (y)	Total Output (x)
Sector 1	150/1000	500/2000	350	1000
Sector 2	200/1000	100/2000	1700	2000

	Sector 1	Sector 2
Sector 1	0.15	0.25
Sector 2	0.20	0.05

Toy Model of a Two-Sector Economy

(Miller and Blair, 2009)



What if Sector 1 final demand drops by **100 units**?

	Sector 1	Sector 2	Final Demand (y)	Total Output (x)
Sector 1	150	500	**250**	**?**
Sector 2	200	100	1700	**?**

Toy Model of a Two-Sector Economy

(Miller and Blair, 2009)

$$A = \begin{bmatrix} 0.15 & 0.25 \\ 0.20 & 0.05 \end{bmatrix}$$

$$(I - A)^{-1} = \begin{bmatrix} 1.25 & 0.33 \\ 0.26 & 1.12 \end{bmatrix}$$

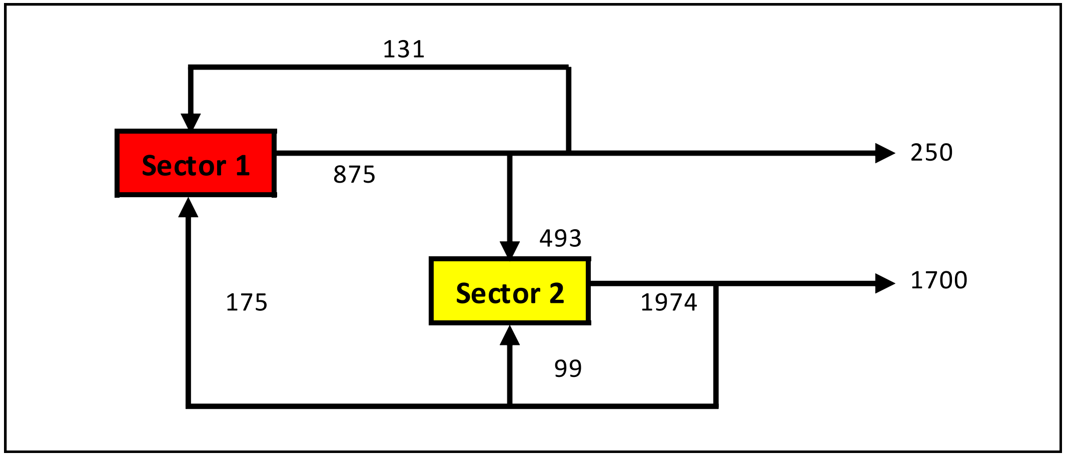
$$(I - A) = \begin{bmatrix} 0.85 & -0.25 \\ -0.20 & 0.95 \end{bmatrix}$$

$$(I - A)^{-1} y = \begin{bmatrix} 1.25(250) + 0.33(1700) \\ 0.26(250) + 1.12(1700) \end{bmatrix} = \begin{bmatrix} 875 \\ 1974 \end{bmatrix}$$

	Sector 1	Sector 2	Final Demand (y)	Total Output (x)
Sector 1	150	500	**250**	**?**
Sector 2	200	100	1700	**?**

Toy Model of a Two-Sector Economy

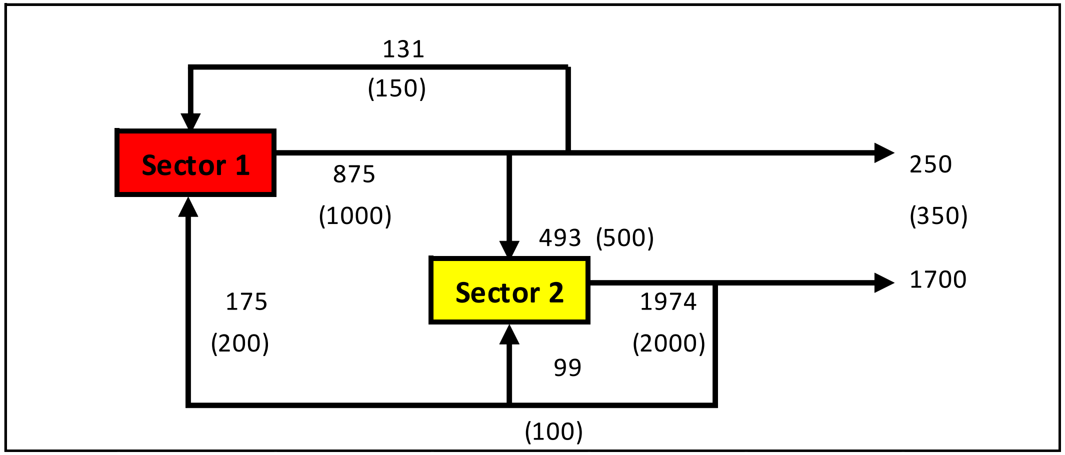
(Miller and Blair, 2009)



	Sector 1	Sector 2	Final Demand (y)	Total Output (x)
Sector 1	150	500	250	**875**
Sector 2	200	100	1700	**1974**

Toy Model of a Two-Sector Economy

(Miller and Blair, 2009)



	Final Demand (y)	Total Output (x)
Sector 1	10%	12.5%
Sector 2	0%	1.3%

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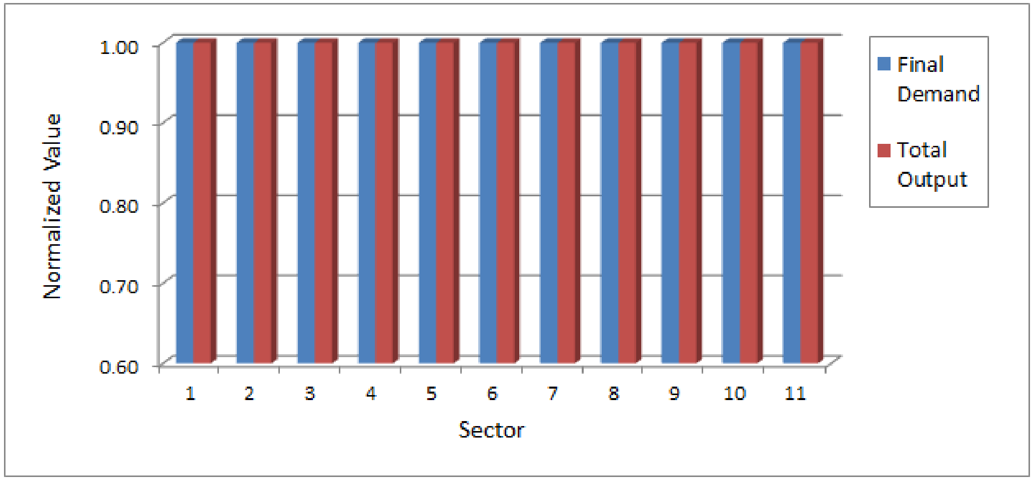
Simulation Parameters

- What are the potential adverse economic impacts of losing final demand for the “Private Services” sector?
- We use Philippine 11-sector IO data from 2000 as a test case

Sample IO Data (Philippines, 11 Sectors)

(https://psa.gov.ph/statistics/input-output)

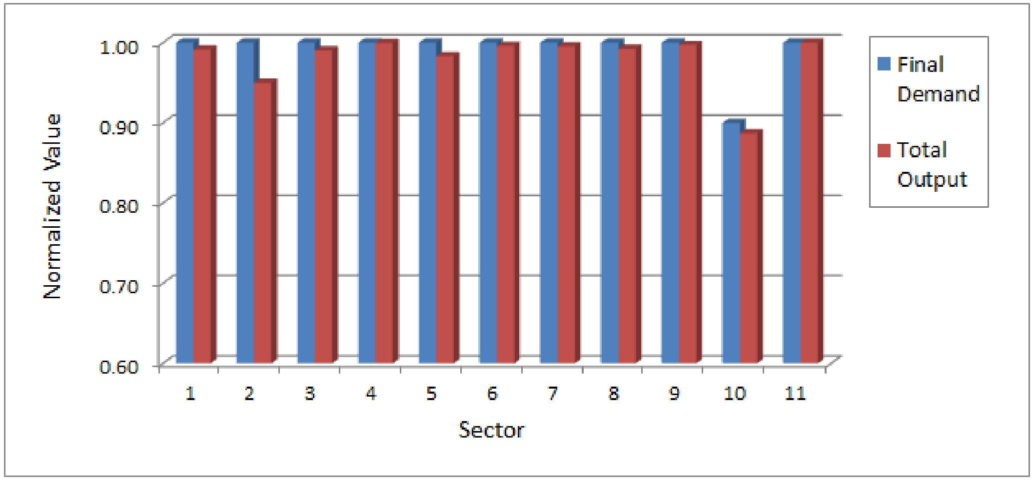


Baseline or normal state with **zero inoperability**

Code	DESCRIPTION	001	002	003	004	005	006	007	008	009	010	011	Final Demand	Total Output
001	Agriculture, Fishery and Forestry	1.109	0.046	0.195	0.067	0.031	0.073	0.058	0.034	0.010	0.091	0.040	236,057	686,745
002	Mining and Quarrying	0.014	1.033	0.084	0.055	0.087	0.031	0.023	0.014	0.005	0.029	0.015	-151,600	37,788
003	Manufacturing	0.242	0.343	1.606	0.536	0.238	0.583	0.314	0.236	0.069	0.492	0.240	1,501,120	3,299,139
004	Construction	0.002	0.014	0.002	1.007	0.003	0.002	0.001	0.004	0.009	0.001	0.026	269,486	289,360
005	Electricity, Gas and Water	0.019	0.073	0.045	0.021	1.095	0.024	0.017	0.029	0.006	0.050	0.023	68,669	196,704
006	Transportation, Communication and Storage	0.012	0.027	0.032	0.109	0.021	1.042	0.126	0.069	0.008	0.030	0.033	316,865	514,091
007	Trade	0.029	0.038	0.132	0.058	0.042	0.059	1.029	0.024	0.008	0.053	0.026	511,748	803,519
008	Finance	0.013	0.026	0.021	0.028	0.009	0.042	0.043	1.011	0.034	0.034	0.037	185,135	300,570
009	Real Estate and Ownership of Dwellings	0.002	0.004	0.004	0.010	0.002	0.013	0.009	0.034	1.003	0.012	0.011	256,105	290,760
010	Private Services	0.026	0.099	0.032	0.045	0.040	0.069	0.038	0.195	0.046	1.128	0.082	426,180	659,932
011	Government Services	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	442,004	442,004

Sample IO Data (Philippines, 11 Sectors)

(https://psa.gov.ph/statistics/input-output)

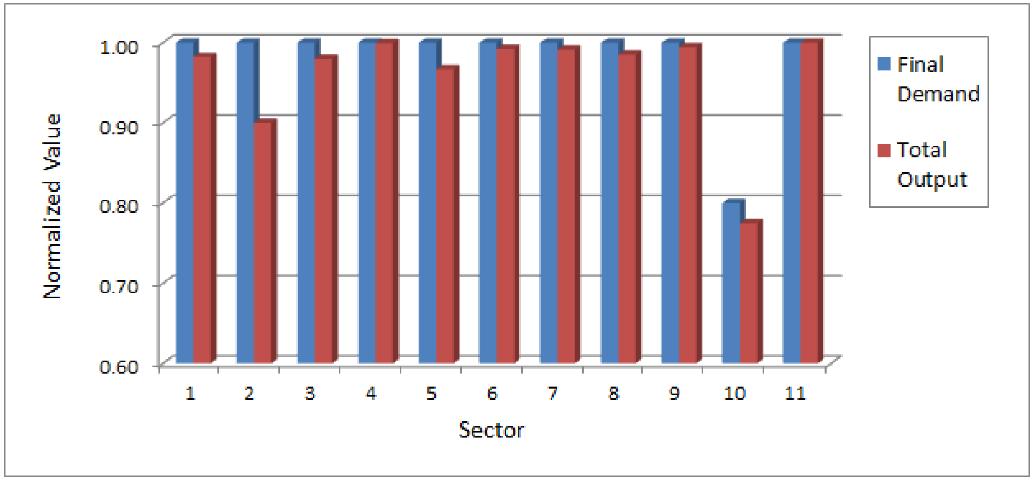


Effect of **10%** demand-side perturbation

Code	DESCRIPTION	001	002	003	004	005	006	007	008	009	010	011	Final Demand	Total Output
001	Agriculture, Fishery and Forestry	1.109	0.046	0.195	0.067	0.031	0.073	0.058	0.034	0.010	0.091	0.040	236,057	680,711
002	Mining and Quarrying	0.014	1.033	0.084	0.055	0.087	0.031	0.023	0.014	0.005	0.029	0.015	-151,600	35,904
003	Manufacturing	0.242	0.343	1.606	0.536	0.238	0.583	0.314	0.236	0.069	0.492	0.240	1,501,120	3,266,690
004	Construction	0.002	0.014	0.002	1.007	0.003	0.002	0.001	0.004	0.009	0.001	0.026	269,486	289,295
005	Electricity, Gas and Water	0.019	0.073	0.045	0.021	1.095	0.024	0.017	0.029	0.006	0.050	0.023	68,669	193,431
006	Transportation, Communication and Storage	0.012	0.027	0.032	0.109	0.021	1.042	0.126	0.069	0.008	0.030	0.033	316,865	512,111
007	Trade	0.029	0.038	0.132	0.058	0.042	0.059	1.029	0.024	0.008	0.053	0.026	511,748	800,020
008	Finance	0.013	0.026	0.021	0.028	0.009	0.042	0.043	1.011	0.034	0.034	0.037	185,135	298,343
009	Real Estate and Ownership of Dwellings	0.002	0.004	0.004	0.010	0.002	0.013	0.009	0.034	1.003	0.012	0.011	256,105	289,968
010	Private Services	0.026	0.099	0.032	0.045	0.040	0.069	0.038	0.195	0.046	1.128	0.082	360,187	585,478
011	Government Services	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	442,004	442,004

Sample IO Data (Philippines, 11 Sectors)

(https://psa.gov.ph/statistics/input-output)

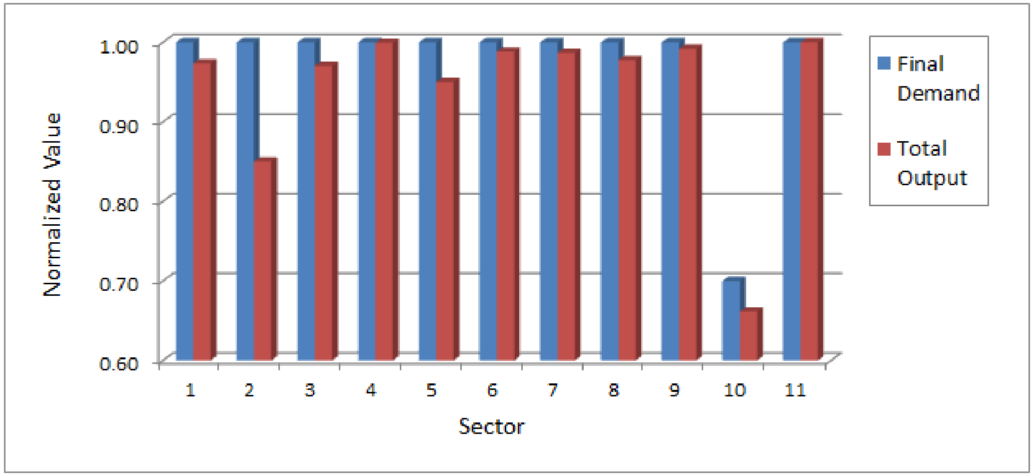


Effect of **20%** demand-side perturbation

Code	DESCRIPTION	001	002	003	004	005	006	007	008	009	010	011	Final Demand	Total Output
001	Agriculture, Fishery and Forestry	1.109	0.046	0.195	0.067	0.031	0.073	0.058	0.034	0.010	0.091	0.040	236,057	674,678
002	Mining and Quarrying	0.014	1.033	0.084	0.055	0.087	0.031	0.023	0.014	0.005	0.029	0.015	-151,600	34,021
003	Manufacturing	0.242	0.343	1.606	0.536	0.238	0.583	0.314	0.236	0.069	0.492	0.240	1,501,120	3,234,242
004	Construction	0.002	0.014	0.002	1.007	0.003	0.002	0.001	0.004	0.009	0.001	0.026	269,486	289,229
005	Electricity, Gas and Water	0.019	0.073	0.045	0.021	1.095	0.024	0.017	0.029	0.006	0.050	0.023	68,669	190,158
006	Transportation, Communication and Storage	0.012	0.027	0.032	0.109	0.021	1.042	0.126	0.069	0.008	0.030	0.033	316,865	510,131
007	Trade	0.029	0.038	0.132	0.058	0.042	0.059	1.029	0.024	0.008	0.053	0.026	511,748	796,522
008	Finance	0.013	0.026	0.021	0.028	0.009	0.042	0.043	1.011	0.034	0.034	0.037	185,135	296,115
009	Real Estate and Ownership of Dwellings	0.002	0.004	0.004	0.010	0.002	0.013	0.009	0.034	1.003	0.012	0.011	256,105	289,176
010	Private Services	0.026	0.099	0.032	0.045	0.040	0.069	0.038	0.195	0.046	1.128	0.082	294,194	511,023
011	Government Services	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	442,004	442,004

Sample IO Data (Philippines, 11 Sectors)

(https://psa.gov.ph/statistics/input-output)



Effect of **30%** demand-side perturbation

Code	DESCRIPTION	001	002	003	004	005	006	007	008	009	010	011	Final Demand	Total Output
001	Agriculture, Fishery and Forestry	1.109	0.046	0.195	0.067	0.031	0.073	0.058	0.034	0.010	0.091	0.040	236,057	668,644
002	Mining and Quarrying	0.014	1.033	0.084	0.055	0.087	0.031	0.023	0.014	0.005	0.029	0.015	-151,600	32,138
003	Manufacturing	0.242	0.343	1.606	0.536	0.238	0.583	0.314	0.236	0.069	0.492	0.240	1,501,120	3,201,793
004	Construction	0.002	0.014	0.002	1.007	0.003	0.002	0.001	0.004	0.009	0.001	0.026	269,486	289,164
005	Electricity, Gas and Water	0.019	0.073	0.045	0.021	1.095	0.024	0.017	0.029	0.006	0.050	0.023	68,669	186,886
006	Transportation, Communication and Storage	0.012	0.027	0.032	0.109	0.021	1.042	0.126	0.069	0.008	0.030	0.033	316,865	508,151
007	Trade	0.029	0.038	0.132	0.058	0.042	0.059	1.029	0.024	0.008	0.053	0.026	511,748	793,024
008	Finance	0.013	0.026	0.021	0.028	0.009	0.042	0.043	1.011	0.034	0.034	0.037	185,135	293,887
009	Real Estate and Ownership of Dwellings	0.002	0.004	0.004	0.010	0.002	0.013	0.009	0.034	1.003	0.012	0.011	256,105	288,384
010	Private Services	0.026	0.099	0.032	0.045	0.040	0.069	0.038	0.195	0.046	1.128	0.082	228,201	436,568
011	Government Services	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	442,004	442,004

Outline of Presentation

- ❑ Risk analysis and input-output models
- ❑ A “toy model” tutorial
- ❑ Analysis using low-resolution Philippine data
- ❑ Conclusions and further research opportunities

Key Lessons

- After immediate losses (casualties and damage to property) in the aftermath of disasters, economic repercussions need to be understood and addressed
- Economic sectors can be directly or indirectly affected, leading to further losses with socio-economic implications
- Total losses in real economic systems will exceed initial losses due to amplification effects

Conclusions and Prospects

- Disasters and other disruptive events can generate economic "ripple effects" which are not immediately obvious
- IO models provide a means of estimating these effects and planning countermeasures
- What we need:
  - Disaggregated IO data for analysis of regional effects
  - Working IO knowledge in agencies and LGUs
  - Horizon scanning for future disruptive events

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Thanks for your attention

Comments and questions are welcome

Or contact me via e-mail:

Raymond R. Tan, Ph.D.
raymond.tan@dlsu.edu.ph