Trade Network Modeling

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Michael J. Puma and colleagues

Next-Generation Food Shock Modeling

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Special thanks to C. Otto, B. Schauburger, A. Heslin, K. Davis, A. Moore, A. Higgins
"Hazards such as dormant volcanoes may operate as limiting factors so rarely that they can be ignored by human populations. Such hazards can be, and regrettably are, ‘coped’ with by the ability of human fertility to compensate for occasional catastrophic mortality” (Halstead & O’Shea, 1989)
Single breadbasket failure... *US Dust Bowl*

1934 Had Worst Drought of Last Thousand Yrs

Source: Cook et al. (2014)
We’re interested in metrics of food security

Food security is defined along four dimensions – and all are challenged

Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. *(FAO definition)*

**Challenges**

- Population growth
- Dietary shifts
- Land constraints
- Climate change
- Geopolitics

**Four dimensions of food security**

- Availability
- Access
- Utilization
- Stability

**Solutions**

- Low-meat diets
- Mitigate climate change
- Increase agric. inputs
- Avoid extreme yield losses
- Promote democracy

*Slide from Schauberger (2019) presentation*
Multi-level analyses required

Localized impacts requiring granular environmental data

International impacts requiring systems-level data

Image modified from Otto (2018) presentation
Start with national food data

Trade and nutrition… Guatemala

Next… Shannon index import score
• Diversity of trade partners
• Diversity of commodities from individual trade partners
• Diversity of commodities from all trade partners

K. Davis & M. Puma for ACToday (a Columbia World Project)
Global env. variables

Drought
Flooding
Flood

Temperature

Fire

e.g. SERVIR and the Composite Drought Index from yesterday

Link to suite of models

A Heslin & M. Puma for MURI migration
Simulating global prices and transmission to national level

Christian Otto and Theresa Falkendal (PIK)

Storylines → Crop Models: LPJmL, APSIM, DSSAT → Production → Trade With Storage (TWIST) model

**TWIST model**

### Observations

- **Simulations w/o reserve**
- **Simulations with reserve**

Source: Schewe, Otto, and Frieler (ERL, 2017); Otto, Schewe, Puma, and Frieler (to be resubmitted)

Assess regional and international food security policies (e.g., food reserves)

Simulating global prices and transmission to national level

Christian Otto and Theresa Falkendal (PIK)

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**TWIST model**

### Observations

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Class of “large” events... inventory-dominated dynamics

Moderated by...

- Connectivity (wheat network)
- Community structure/geopolitics (different commodities)
- Interdependencies (energy network)

Critical threshold
- Connectivity + Homogeneity
- Resistance to change + Local repairs + Critical transitions

When global markets fail... e.g. trade restriction, panic buying, hoarding

Shock to food production

Use reserves

Reduce consumption

Modify trade

Production shock (-20%) from PAK with reserves at 5%

Source: Marchand et al (2016)
Ensemble of shocks

Example parameters
- 20% shock to production
- 50% of reserves available for use
- Use can be reduced by up to 1%

Network
Initialized with historical data from one of the time periods.

Simulations
- Afghanistan
- Albania
- Algeria
Ensemble statistics... *# of supply hits*

- **All countries**
  - 1996-2000: 60 hits
  - 2006-2010: 50 hits

- **Africa only**
  - 1996-2000: 50 hits
  - 2006-2010: 40 hits

Source: Maio & Puma (2017)
Modeling global supply chains

Acclimate: a global agent-based dynamic supply-chain model

Main features

- Micro-economic foundation
- High sectoral + regional detail
- Daily temporal resolution
- Storages and transport delays
- Dynamically resolves
  - Cascading supply-failures
  - Price effects
  - Abrupt regime changes

Sources: Otto, Willner et al. (J Econ Dyn Control, 2017); Willner, Otto, Levermann (Nat Clim Ch, 2018)
CSIRO TraNSIT tool analyses transport and logistics options for agriculture to identify potential cost savings.

INPUT: Transport network and related attributes, vehicle characteristics, production locations and yields, storage and processing locations and throughputs, domestic demand and export points/demand
OUTPUT: freight volumes and people movements across the transport network by time
CODE: Python, Fortran
RUNTIME: minutes per country
RESOLUTION: transport segment and monthly time step
TraNSIT.global – Conceptual Design
by Andrew Higgins & Stephen McFallan

TraNSIT engine data needs, processes and outputs

- Current and Scenario
- Distribution Processes
- Externalities
- Things People Process Environment Commerce

Uncertainty

Transport costs and processes
- Truck
- Train
- Shipping

Supply Chain Model

Simulation data

Network

Optimisation model

Calculation engine

Spatial output

Optimal transport routes and kpi’s

Outputs Db

Verification

Validation

Policy and regulations

Other Processes

Process behaviours

interruptive processes

Transport Network Data

Food paths

Locations

Uncertainty

Production Data

Demand Data

Outputs – what form, input for who?

Network Performance
Thanks!

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