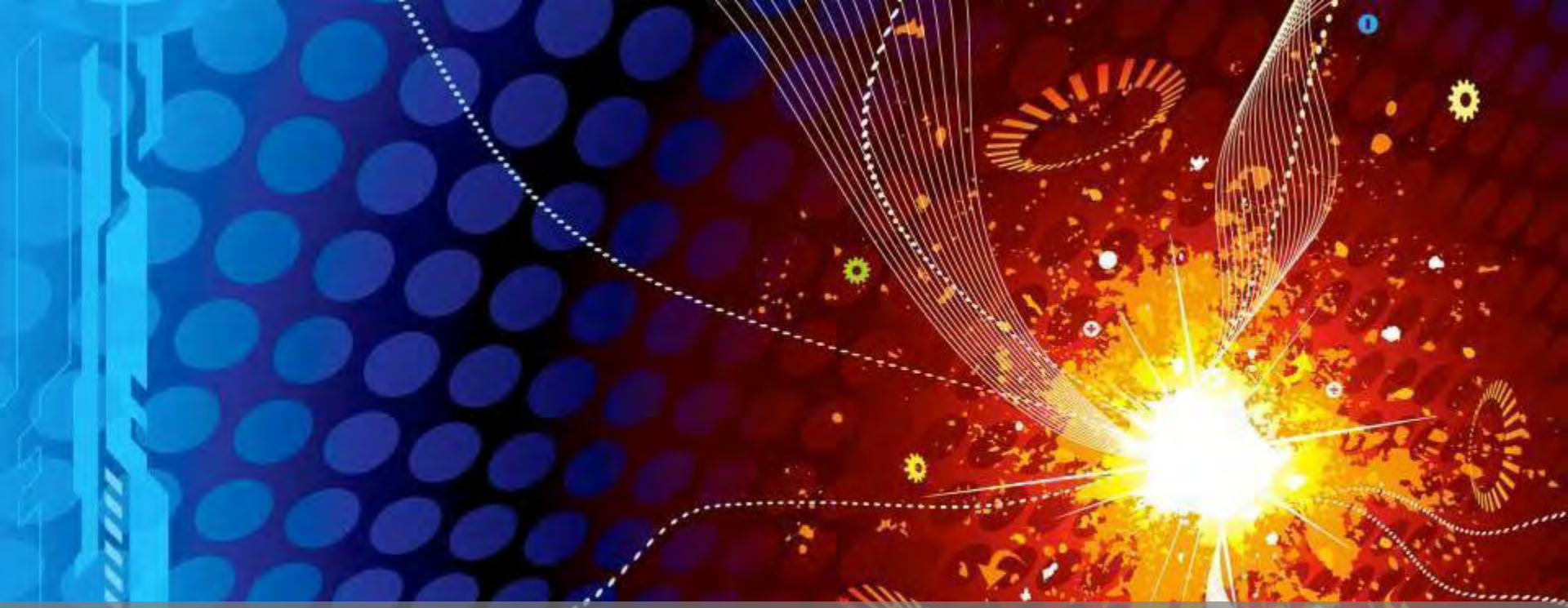


Centre for Risk Studies **Research Showcase**
23 January 2014

Macroeconomic Modelling, International Connectivity and Enterprise Networks

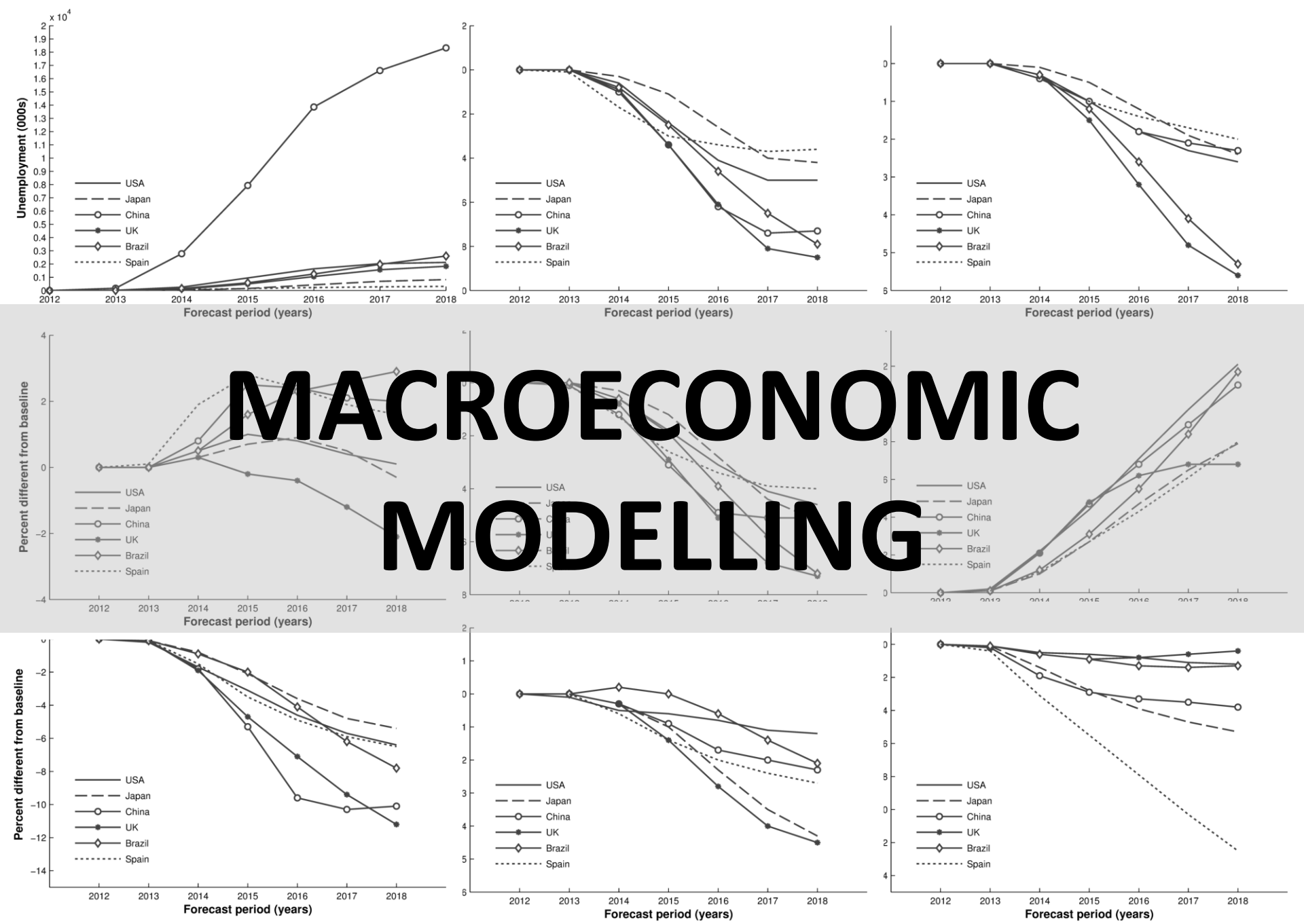
Centre for
Risk Studies

UNIVERSITY OF CAMBRIDGE
Judge Business School

Dr. Scott Kelly
Research Associate

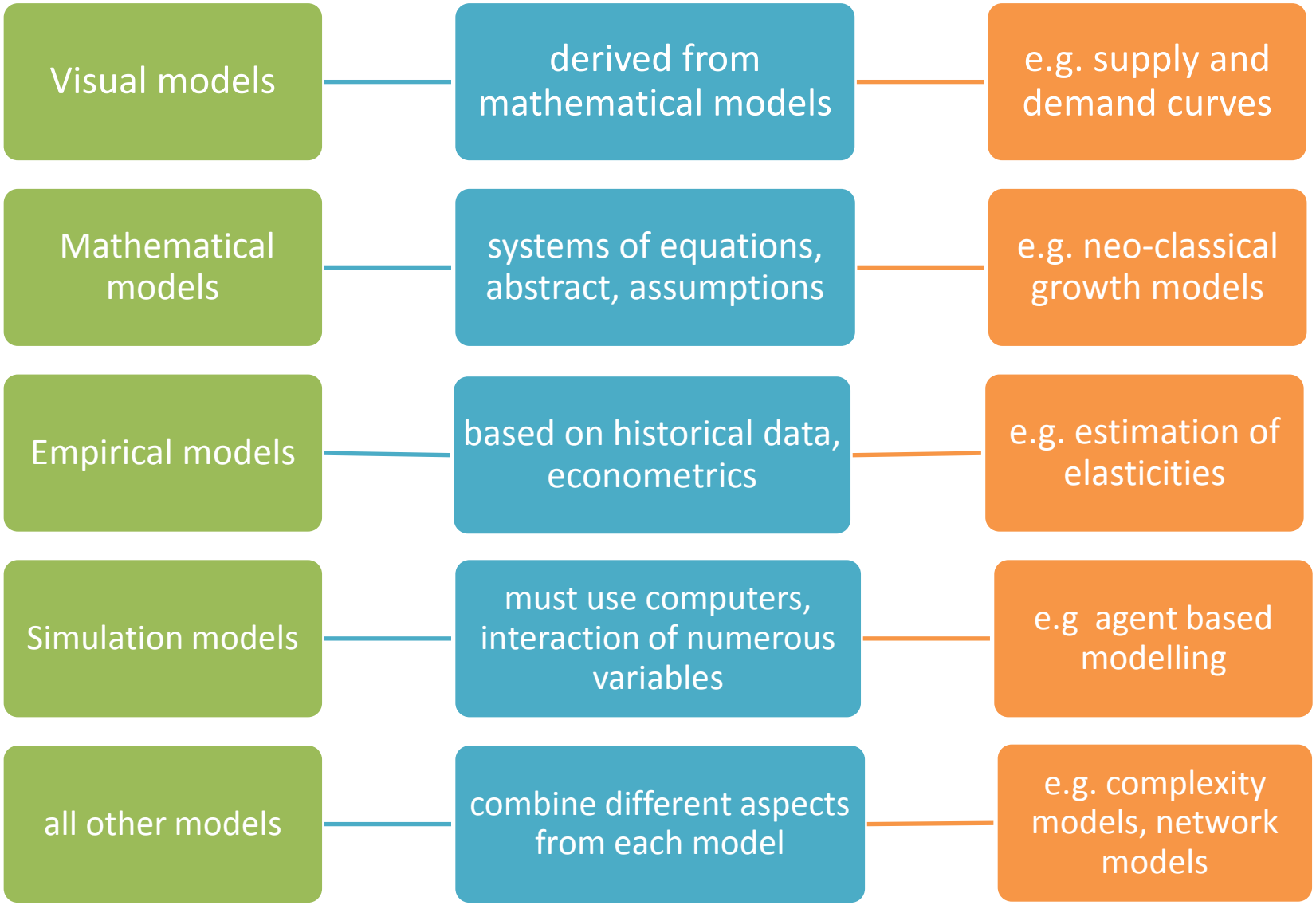
Research areas covered

- **Macroeconomic Analysis Methods and Models**
  - A comparison of several theoretical methods
- **Network Analysis and Global Trade**
  - Analysis of trade links between sectors and countries
- **Input-Output Modelling**
  - Extreme event economic impact analysis (indirect effects)
  - Propagation of risk through supply chains (indirect risks)



MACROECONOMIC MODELLING

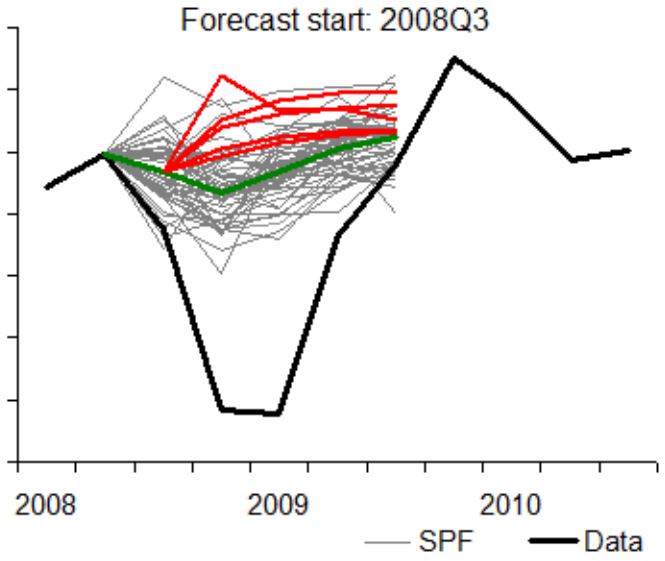
Taxonomy of macroeconomic models

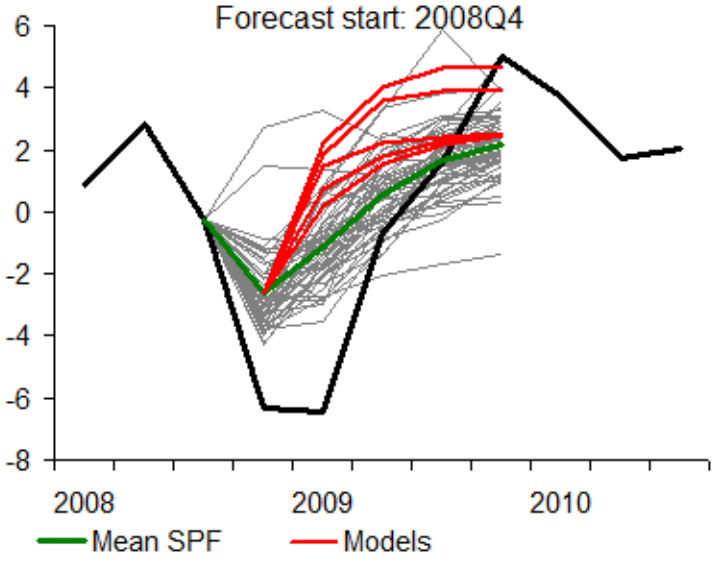


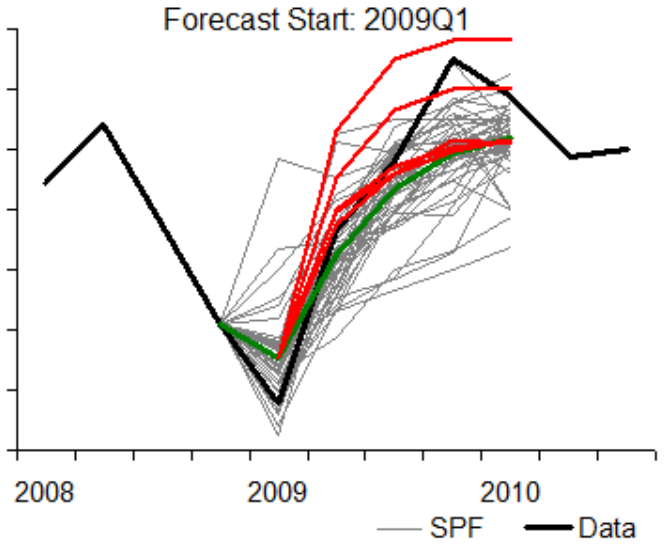
Macroeconomic modelling aproaches

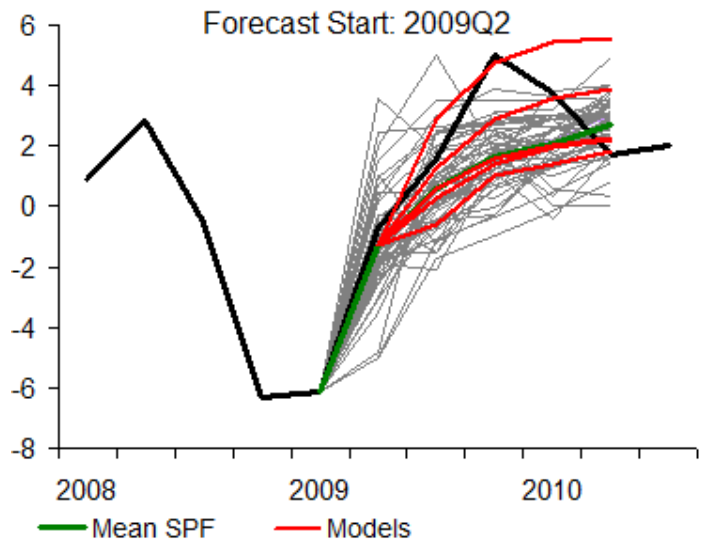
- General Equilibrium Models (GEM)
  - Microfounded assumptions about technology, preferences and budget constraints
  - Generally focus on long-run relationships
- Dynamic Stochastic General Equilibrium Models (DSGE)
  - Exaggerate individual rationality and foresight
  - Understate importance of heterogeneity (competing agents have similar strategies)
  - No better but also not worse than other economic models (Wickens 2012)
- Macro-econometric models (VAR, Panel, Time Series)
  - Use historical data and econometric relationships to make economic projections
- E3 Models (E3MG, GINFORS)
  - Use Input-Output tables to describe financial transactions between economic sectors
  - Good at modelling environment, energy and economic interactions
- Agent Based Computational Economics (ACE)
  - Apply numerical methods to solve complex dynamic problems
  - Heterogeneous agents are given decisions (strategies) and interact with each other
  - Driven by initial conditions, equilibrium may not exists.
  - Considered a bottom-up approach

Macroeconomic models are notoriously bad







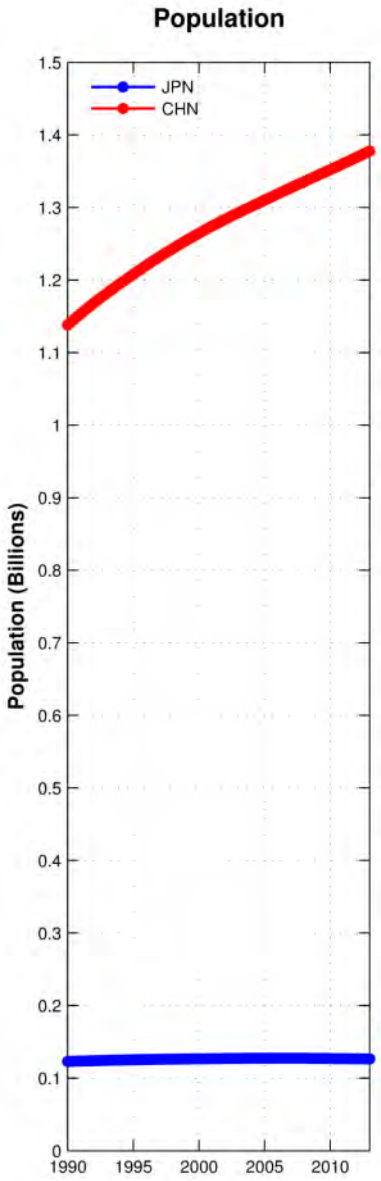


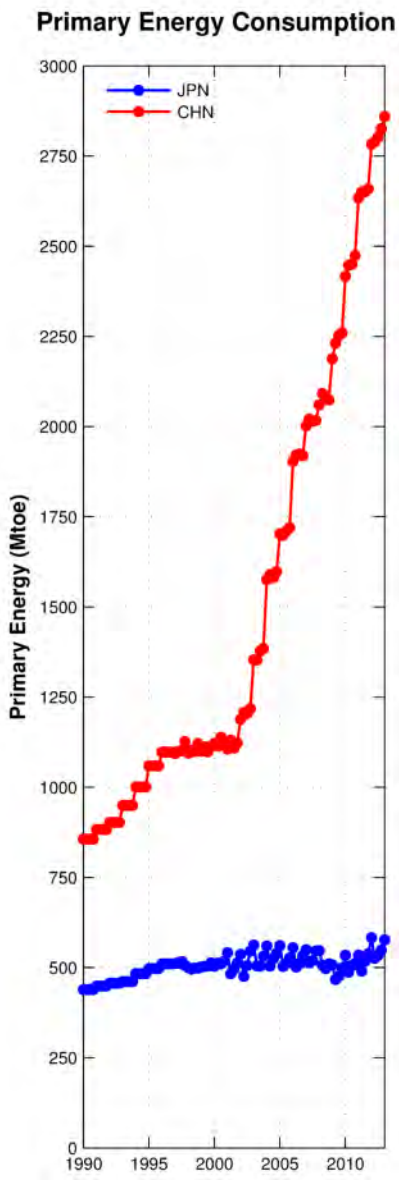
http://economistsview.typepad.com/economistsview/2012/04/the-forecasting-ability-of-modern-macroeconomic-models.html

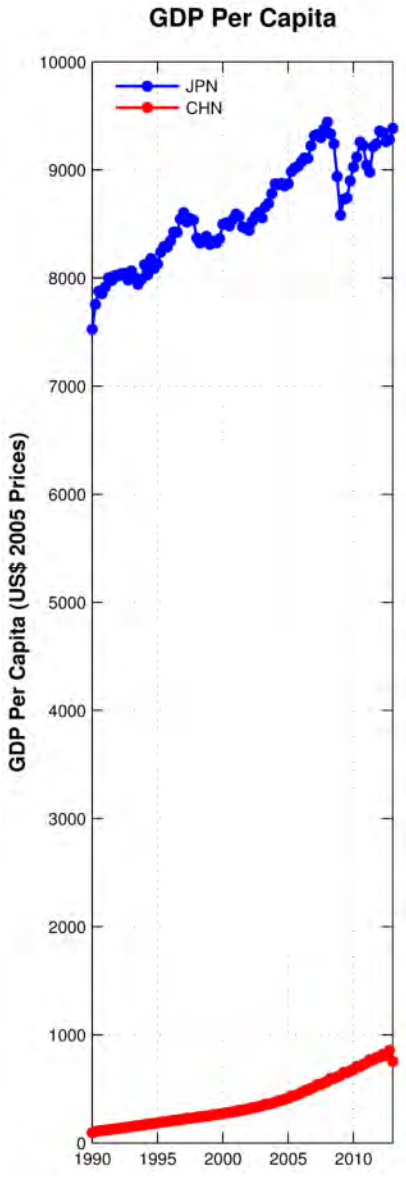
Oxford Global Economic Model (GEM)

- Most widely used macroeconomic model by commerce
- Collaborative research agreement with Oxford Economics
- General Equilibrium Model (GEM) with econometrics
- **5** ,10 and 25 year ahead projections
- 47 Economies (headline forecasts for 30 countries)
- Updated with new data monthly
- "Eclectic Model"
  - Keynesian in short run (demand)
  - Monetarist in the long run (supply)
- Cobb-Douglas production function links capital, labour, and total factor productivity.
- Monetary policy endogenised through 'Taylor Rule'

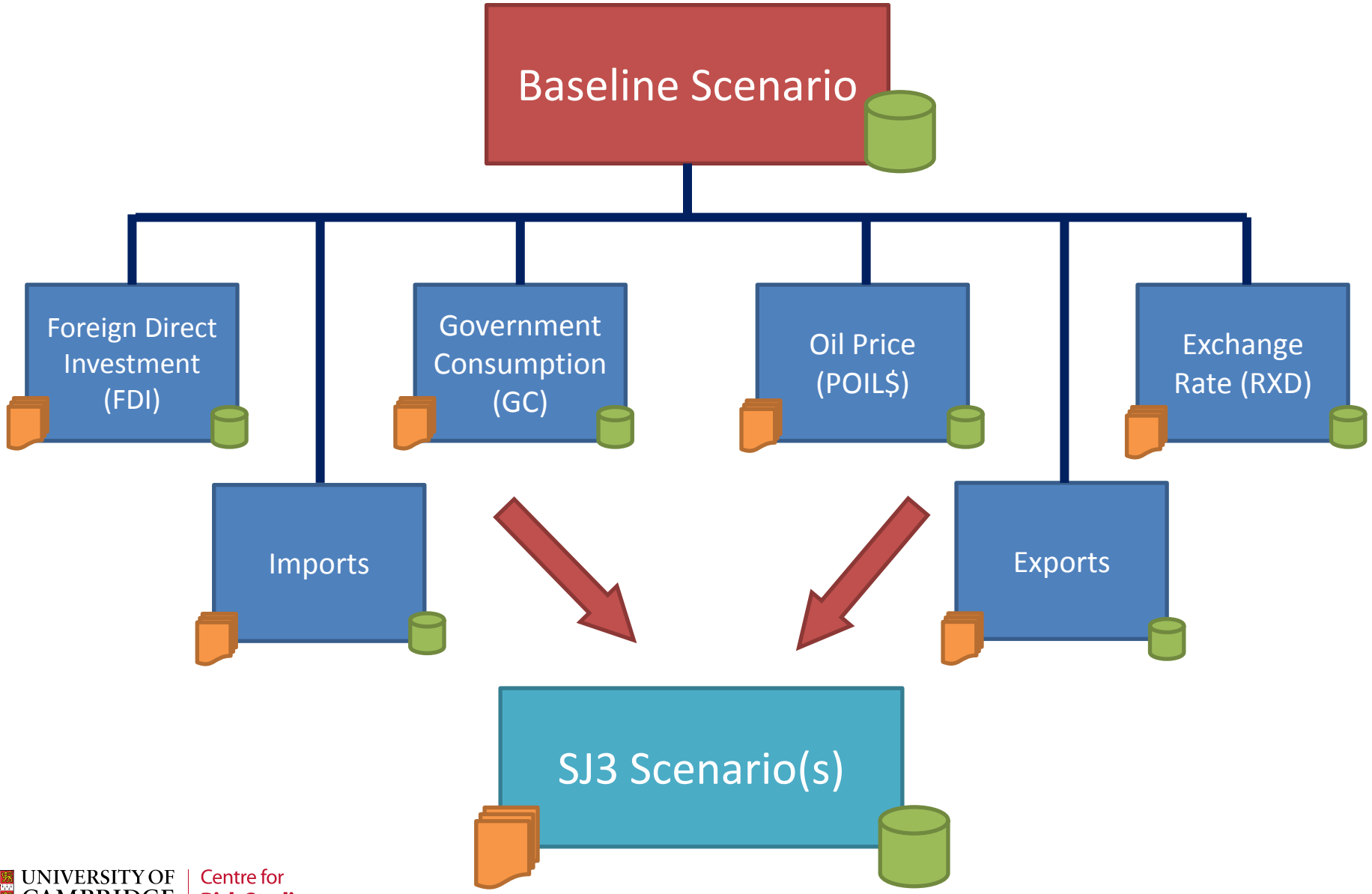
Oxford Economics: China and Japan



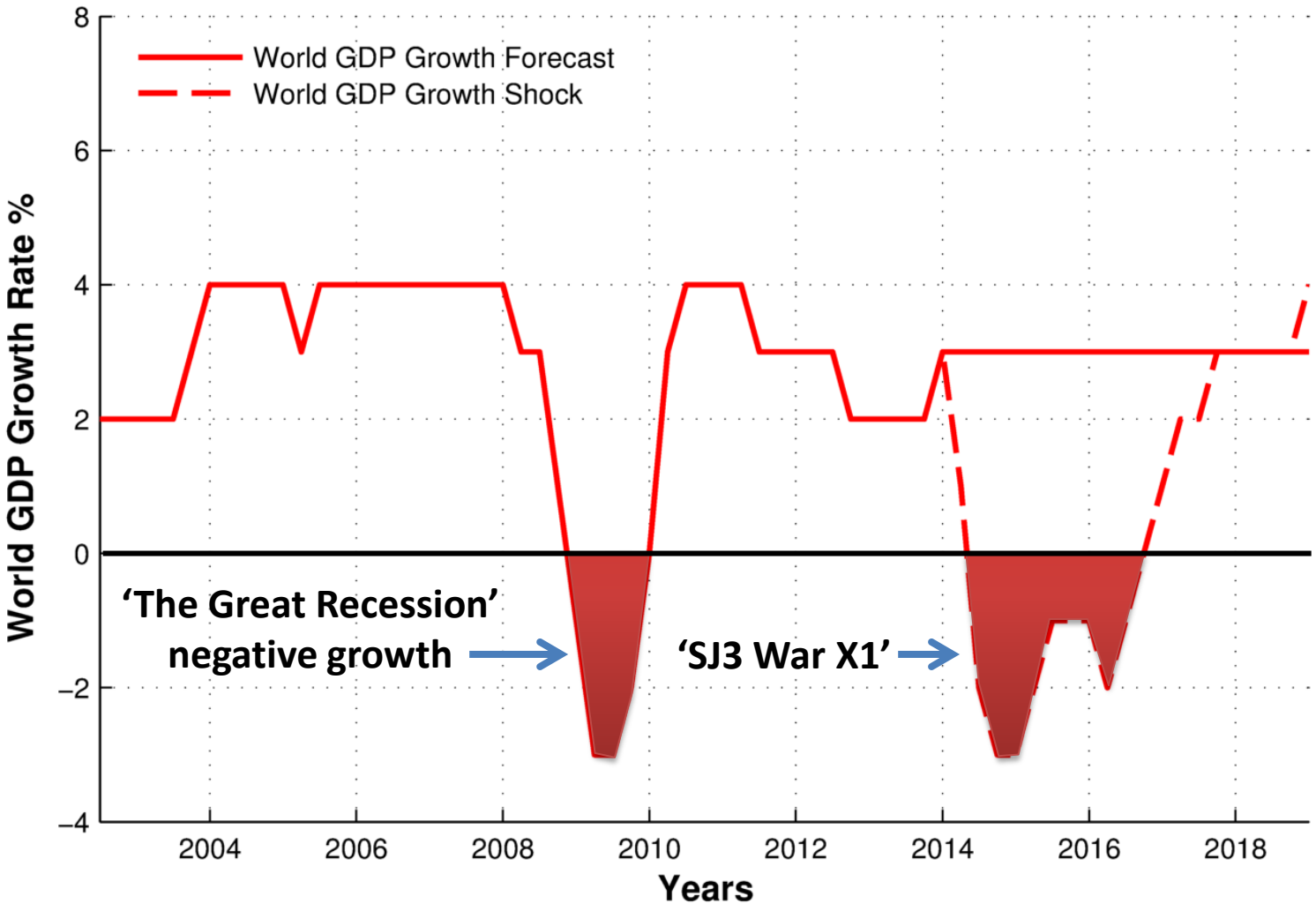


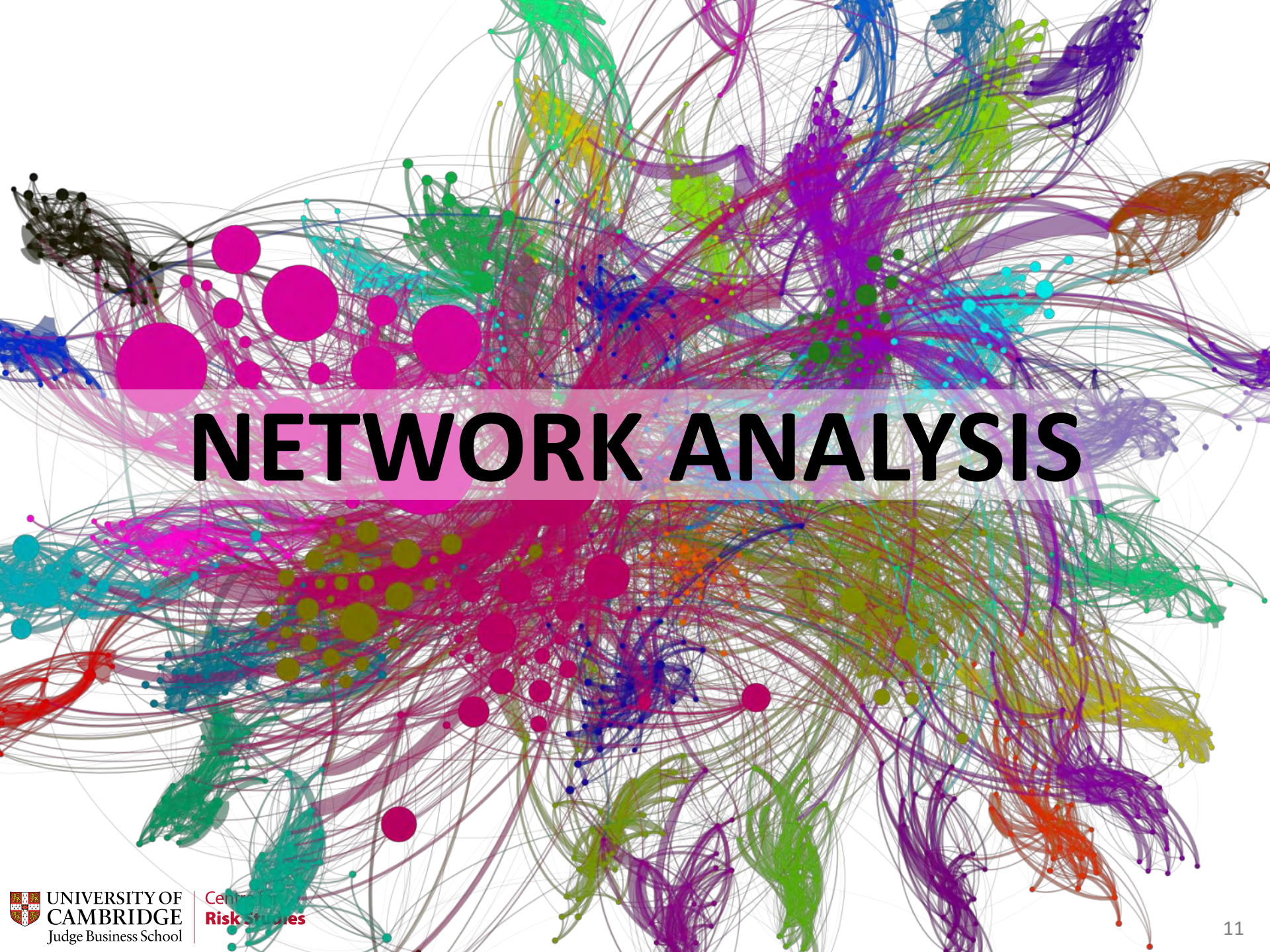


SJ3 Modelling Structure



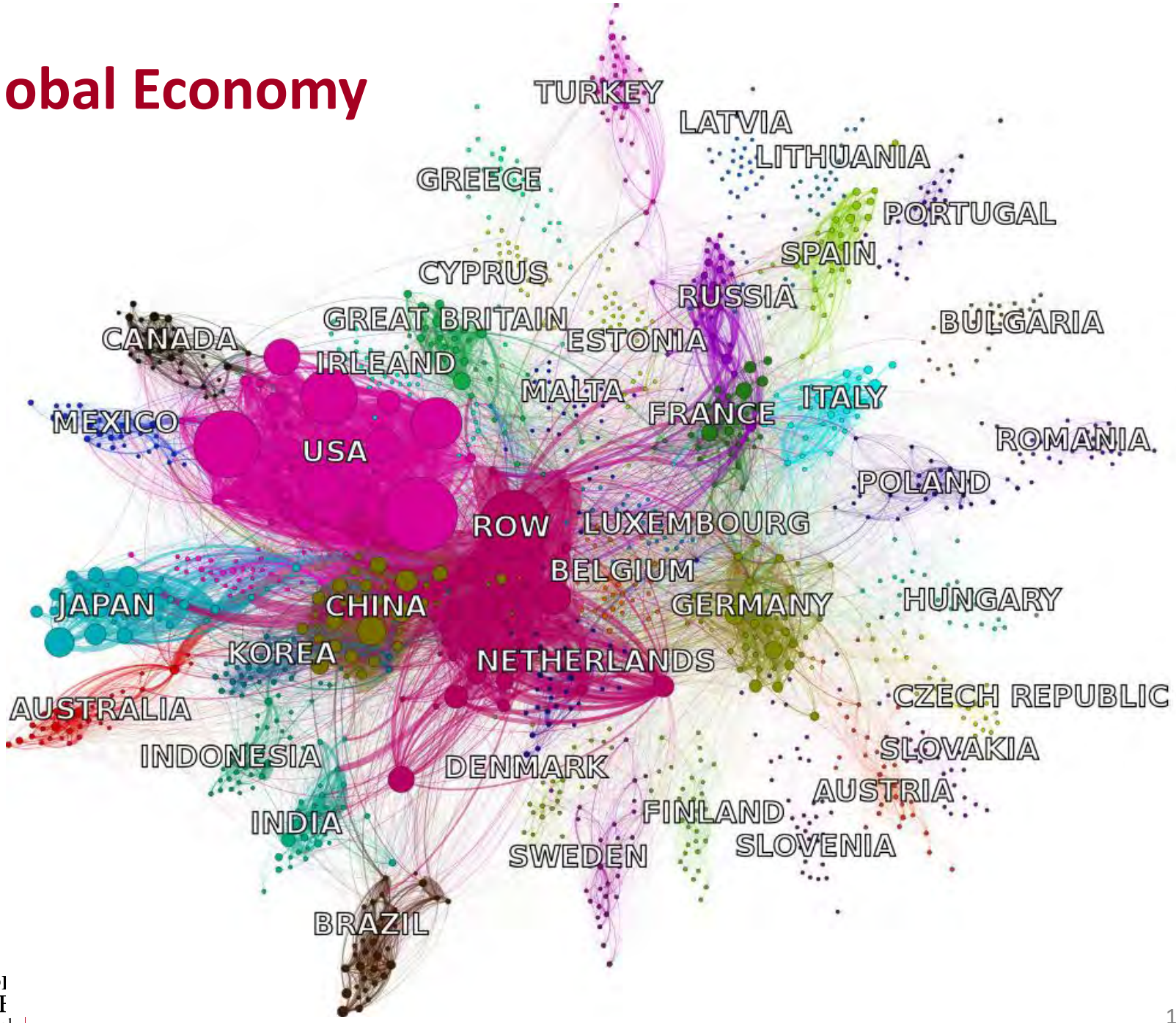
SJ3 X1 Scenario



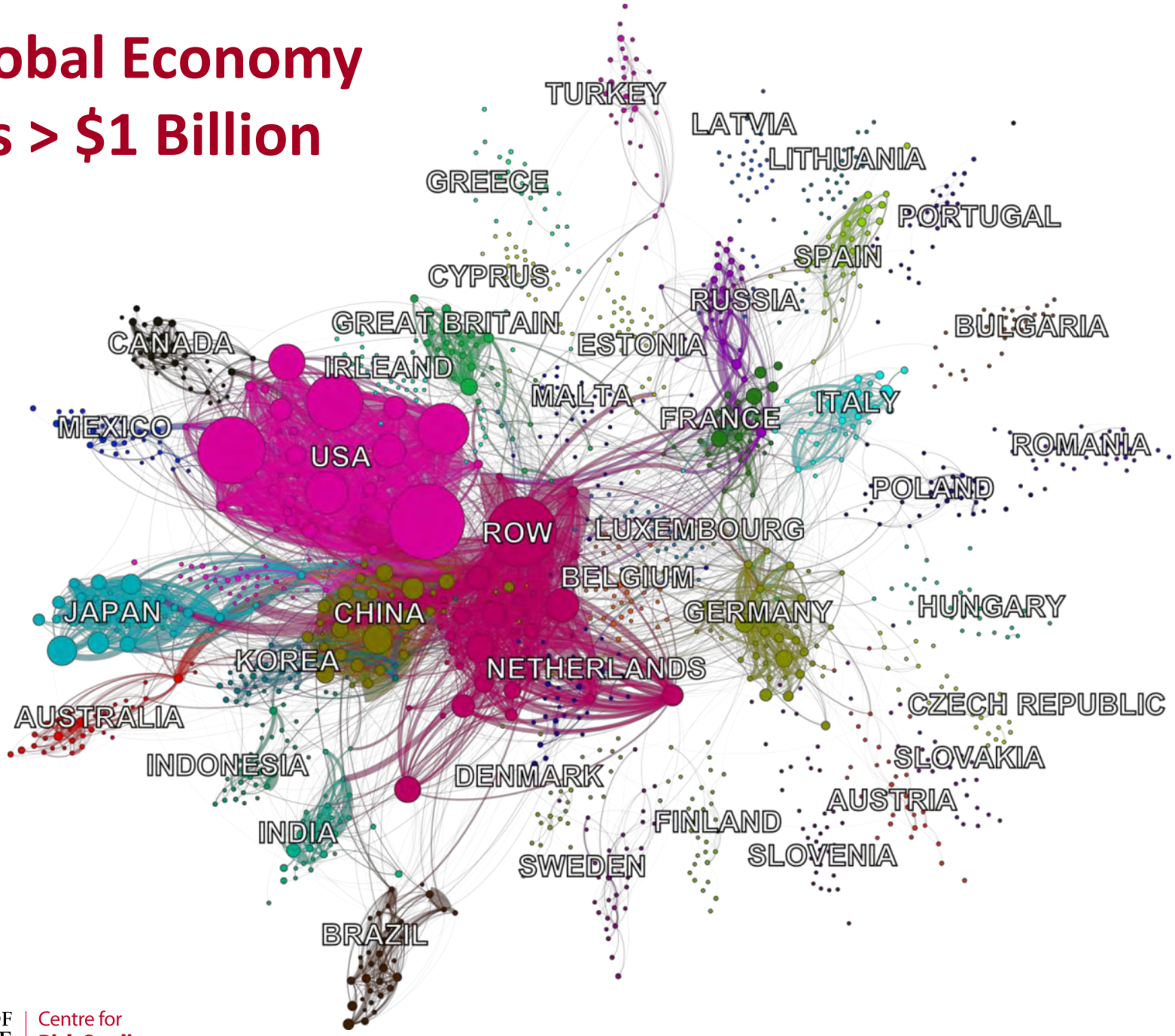


NETWORK ANALYSIS

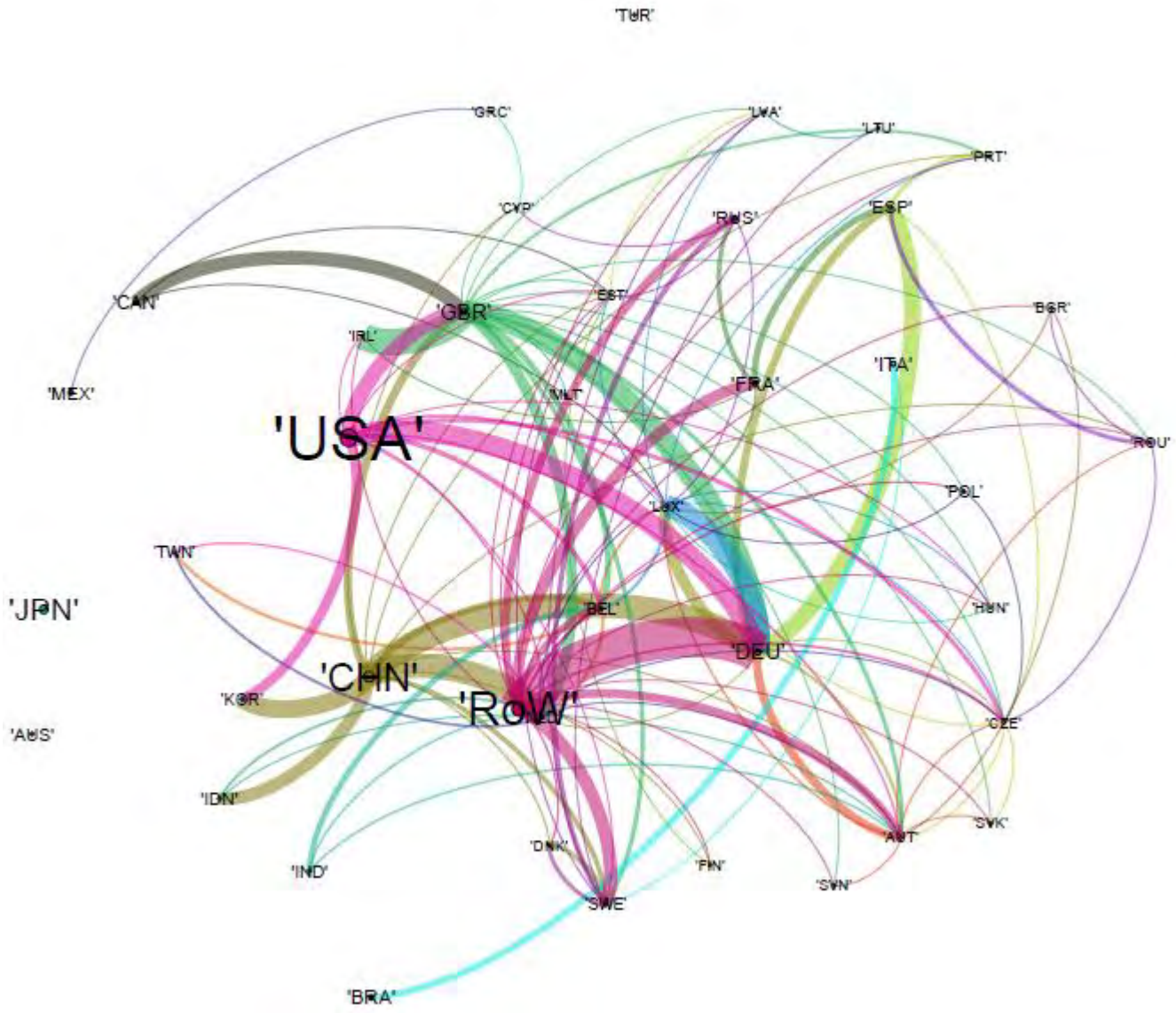
The Global Economy



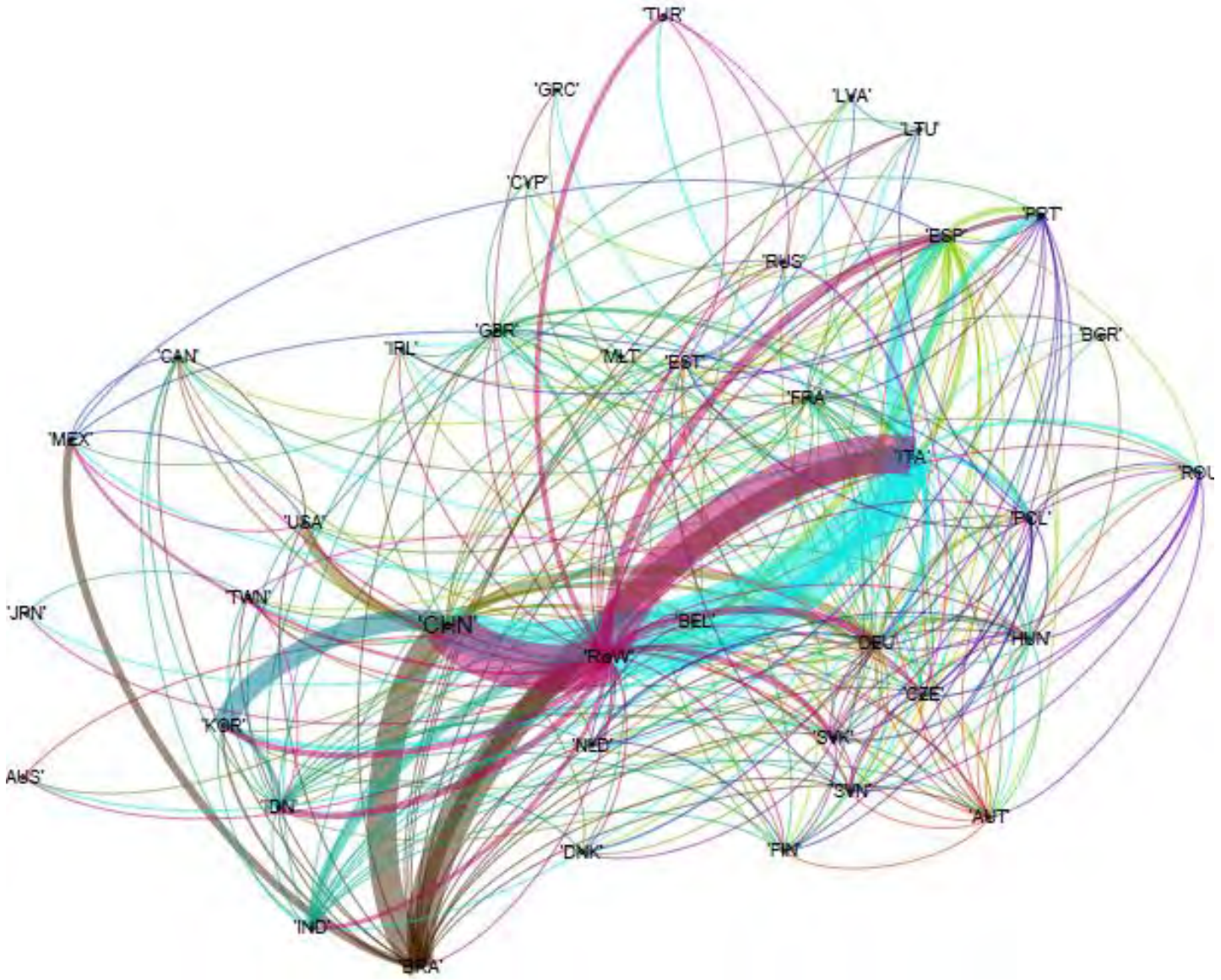
The Global Economy
Sectors > $1 Billion



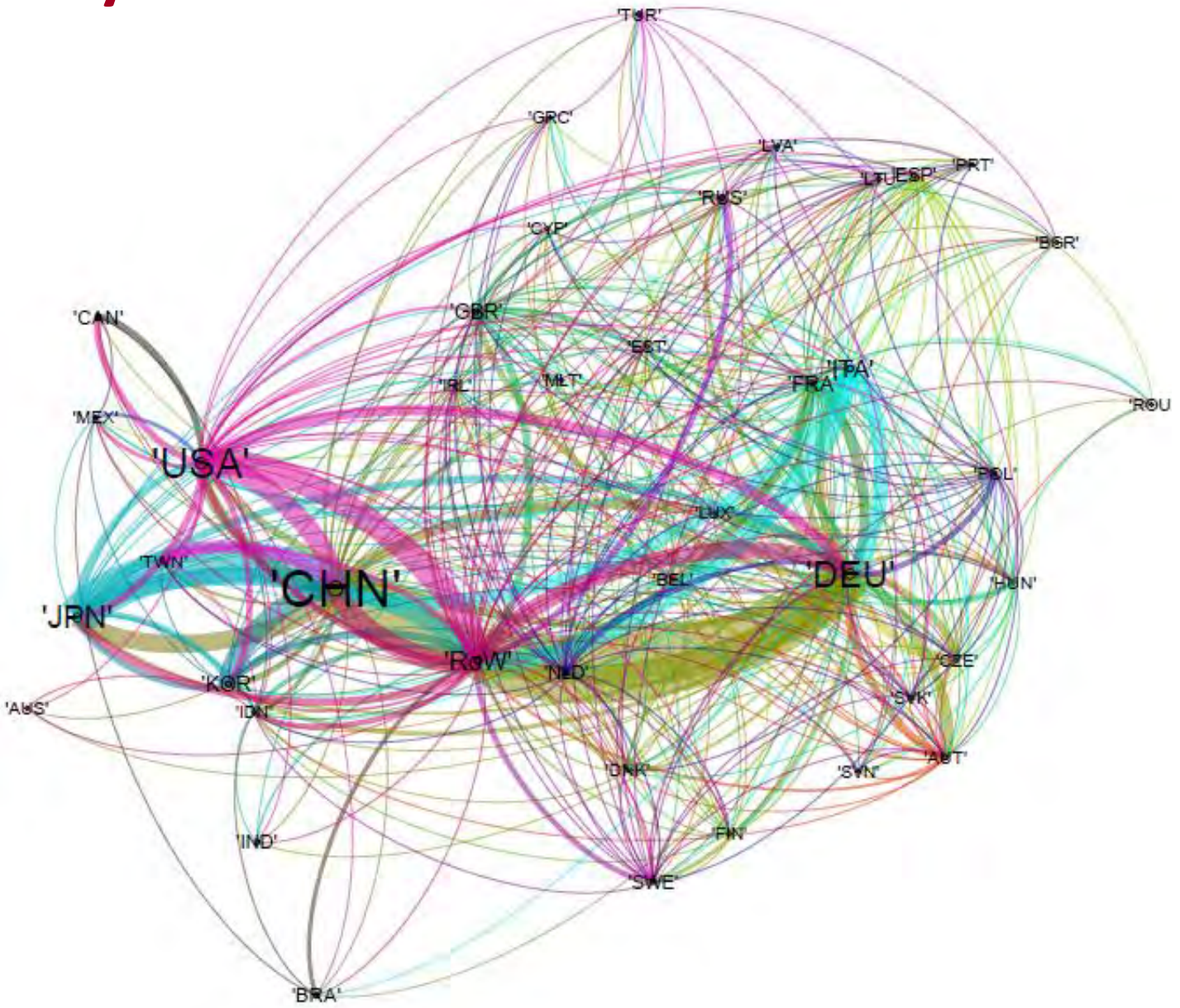
Sector analysis: Telecommunications



Sector analysis: Timber products



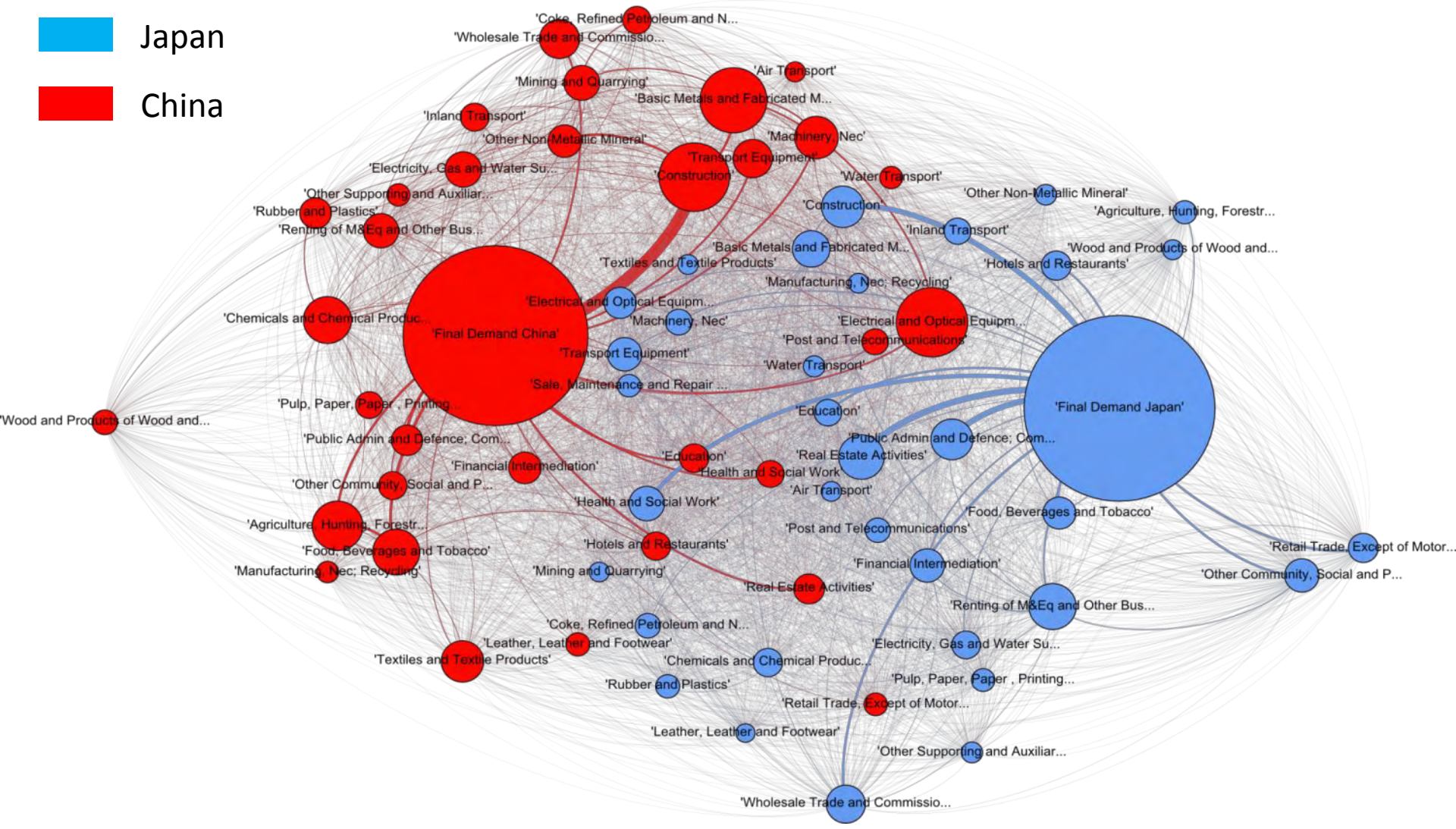
Sector analysis: Electronics



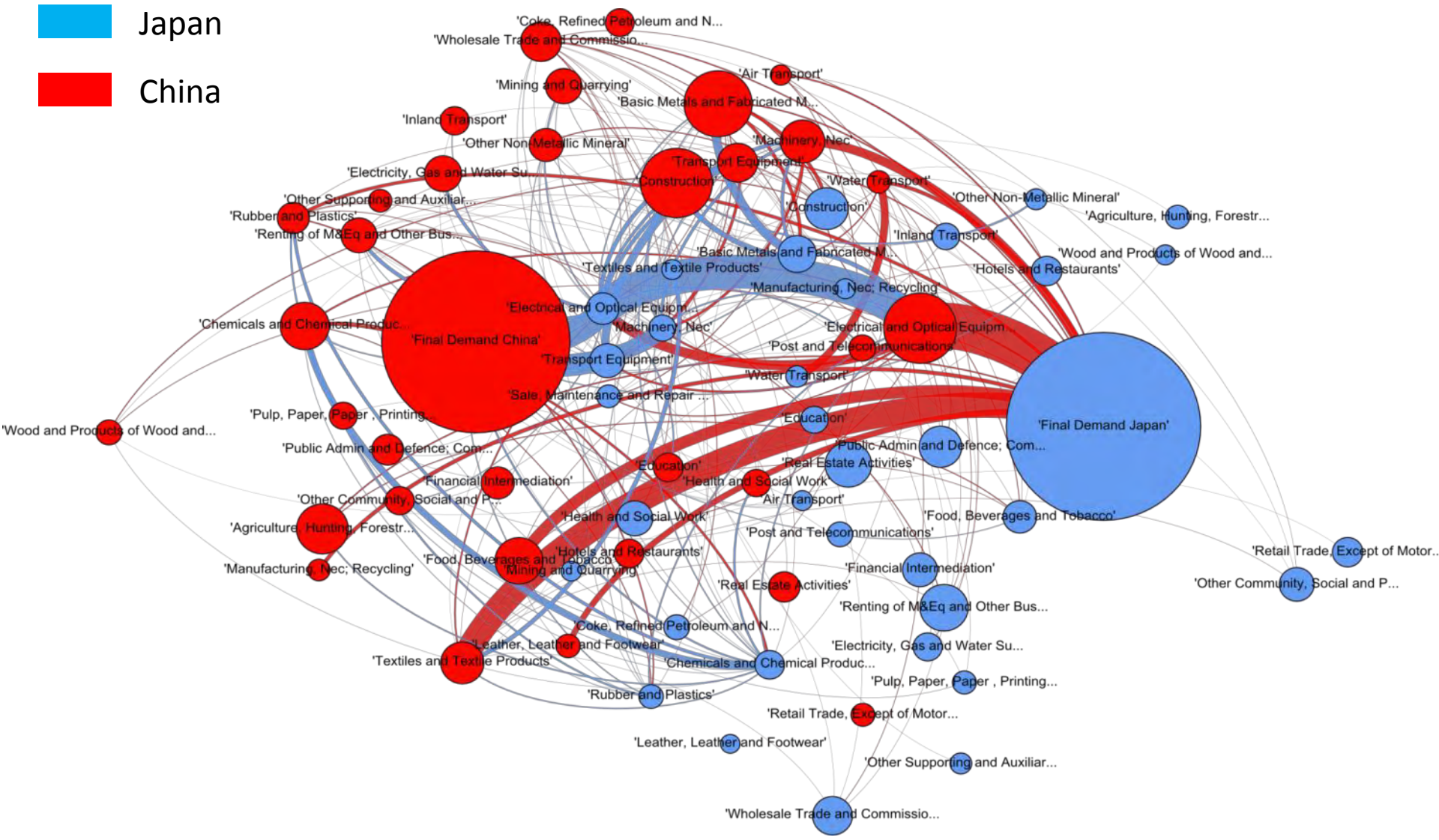
Inter and Intra-trade between Japan and China

Japan

China



Inter-trade between Japan and China

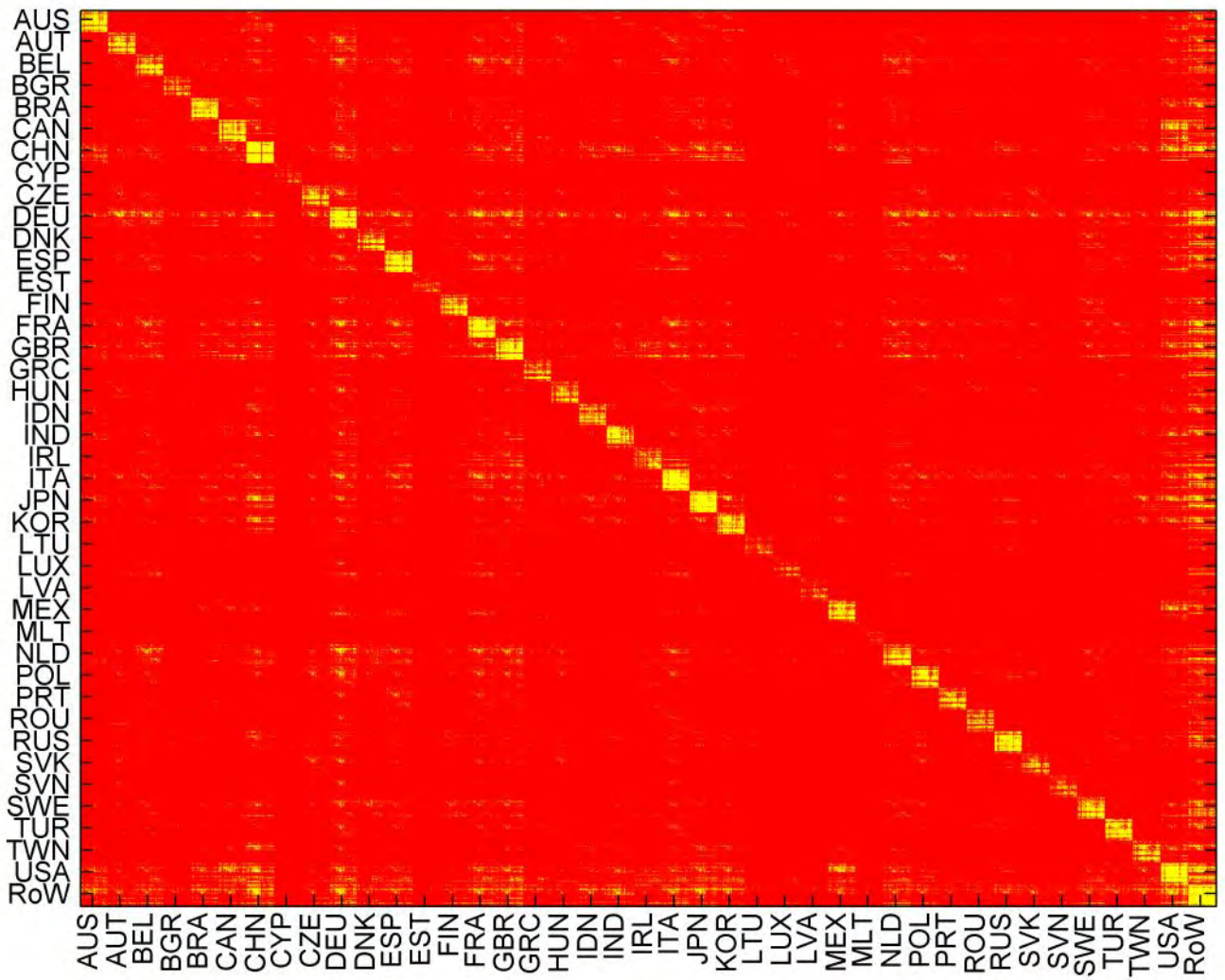


INPUT OUTPUT ANALYSIS

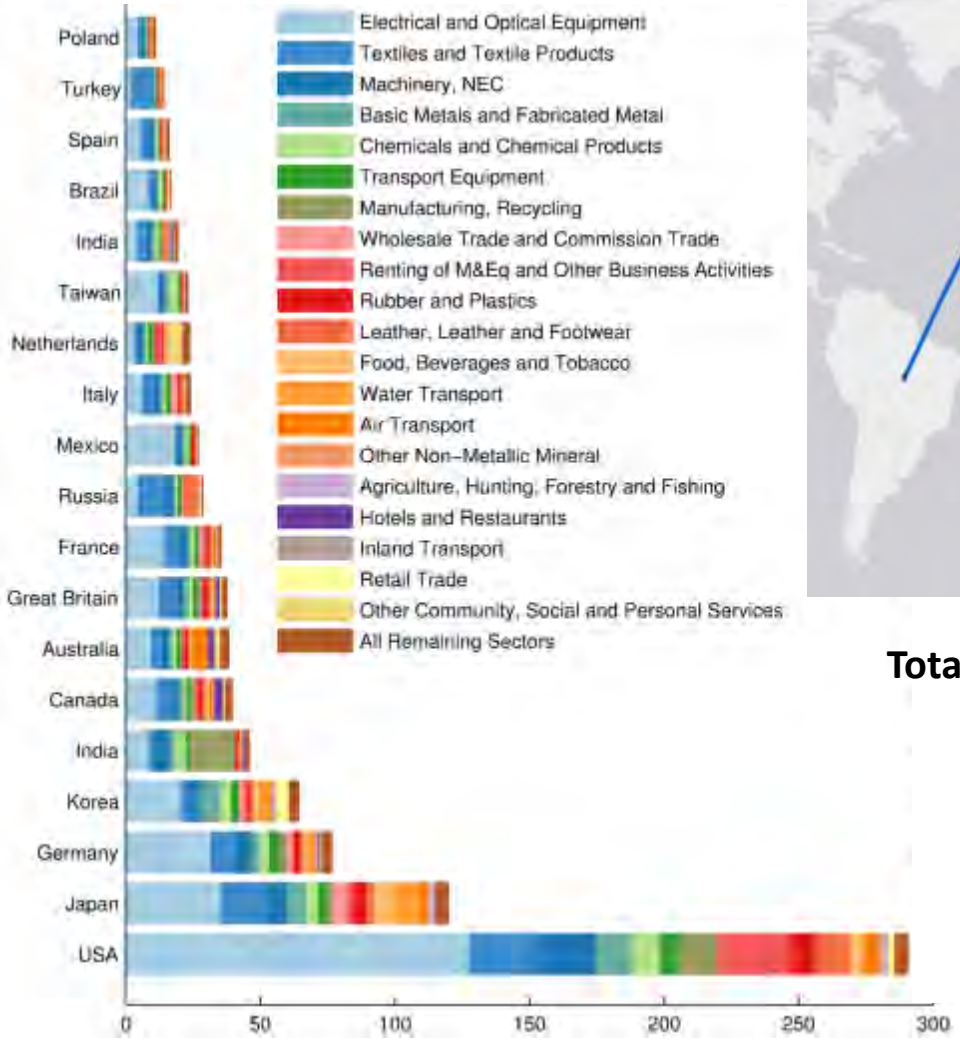
World MRIO tables

Resource	Sectors	Countries	Cover	Source	Reference
WIOD	35	41	1990-2011	www.wiod.org	Marcel P. Timmer.,
EORA	25 (~87)	187	1990-2011	www.worldmrio.com	Lenzen, M., Kanemoto, K., Moran, D., Geschke, A
GTAP Data	57	113	2004	https://www.gtap.agecon.purdue.edu/	Glen Peters et al.
Exiobase	129	43	2000	http://www.exiobase.eu/	Arnold Tucker et al.

WIOD Heat Map



China Exports

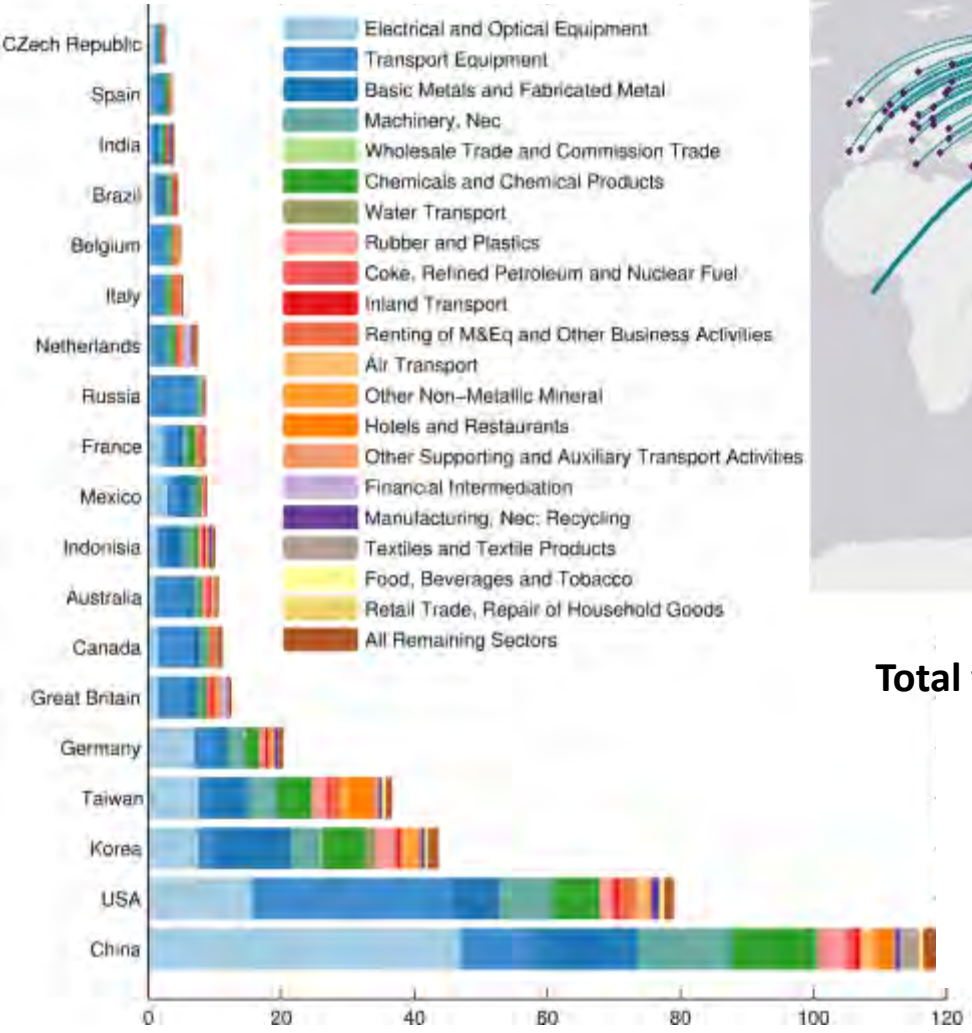


China Export Value by Economic Sector (US$ Billions 2009)

* Excludes exports to the Rest of World

Total value of Chinese exports: $1.33 Trillion ($US 2009)

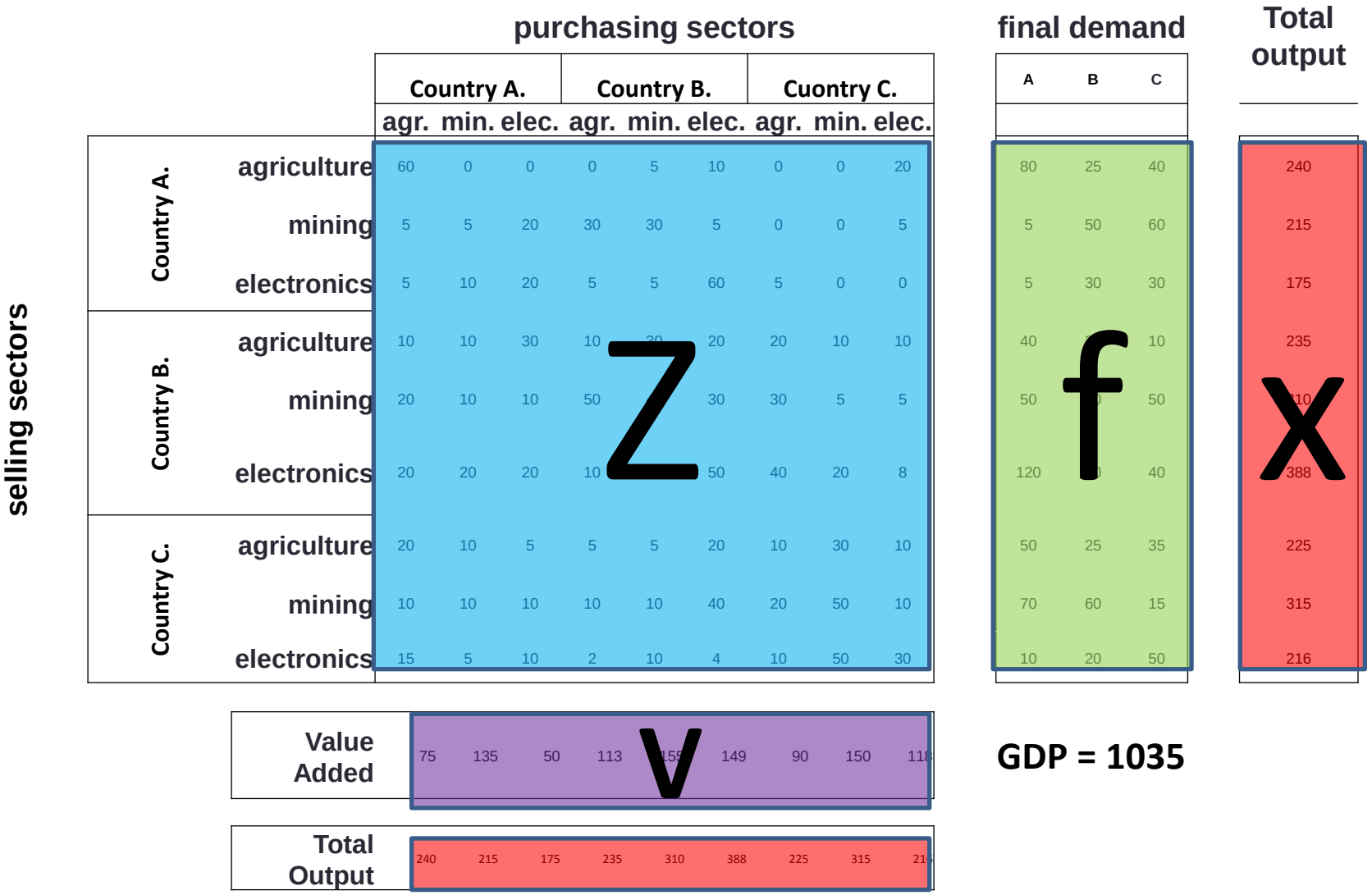
Japan Exports



Japan Export Value by Economic Sector (US$ Billions 2009)

Total value of Chinese exports: $640 Billion ($US 2009)

Construction of IO tables



$$X = Zi + f$$

Doing some basic matrix algebra

We know, $\mathbf{Zi} = \mathbf{Ax}$ and $\mathbf{x} = \mathbf{Zi} + \mathbf{f}$ so.....

$\mathbf{x} = \mathbf{Ax} + \mathbf{f}$ rearrange equation so total output is all on LHS..

$\mathbf{x} - \mathbf{Ax} = \mathbf{f}$ take out common terms..

$\mathbf{x}(\mathbf{I} - \mathbf{A}) = \mathbf{f}$ rearrange with respect to total output

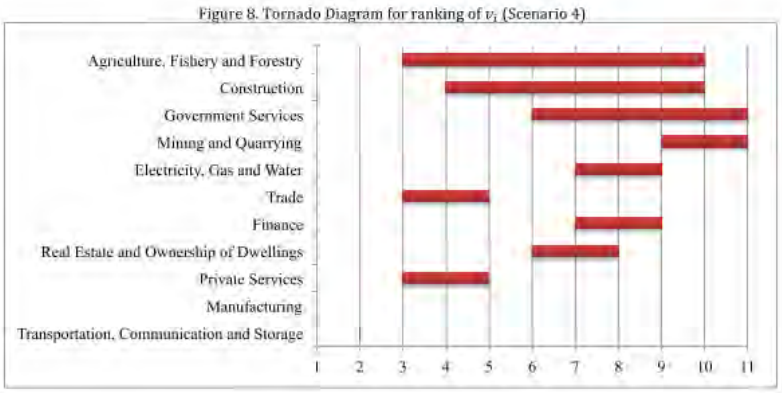
$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}$ now we define $(\mathbf{I} - \mathbf{A})^{-1}$ as $\mathbf{L}$

and we get the famous Leontief Equation

$$\mathbf{x} = \mathbf{Lf}$$

The Inoperability Input-Output Model IIM

Sector vulnerability Indexes



Source: Krista (2013)

Pandemic economic losses

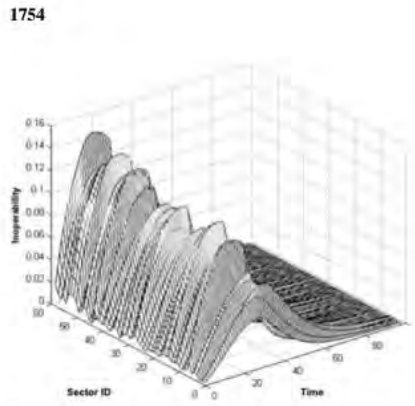


Fig. 10. Inoperability for all sectors, 4-week, 15% attack rate pandemic.

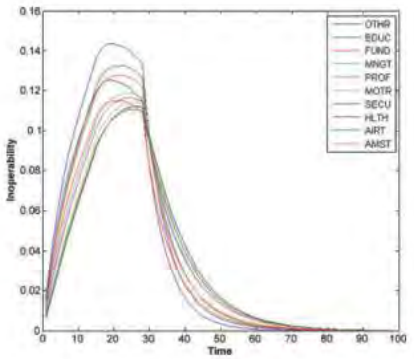
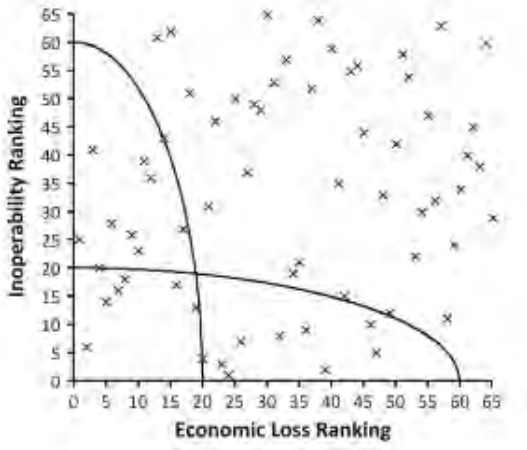


Fig. 12. Inoperability levels of the top 10 sectors most impacted in terms of inoperability.

Inoperability vs economic loss



Source: Resurreccion (2013)

Disruptions to IT infrastructure

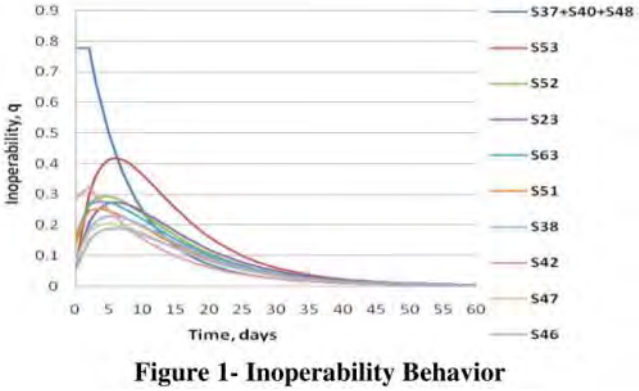
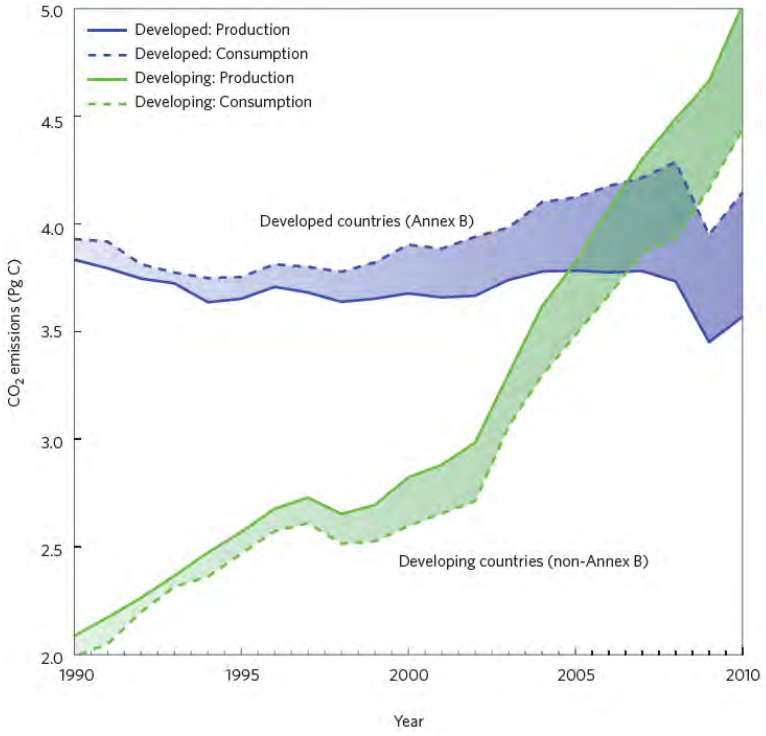


Figure 1- Inoperability Behavior

Source: 10.1109/SIEDS.2012.6215128

Estimating ‘embodied risk’ in global supply chains

- Same theoretical approach to measuring ‘embodied carbon’



Method:

1. Find and develop existing global risk metrics for each country, sector, company or product i.
2. Build risk vector $\mathbf{r}_i$ to represent direct risk for each i.
3. Using IO analysis estimate the Leontief inverse (direct and indirect multipliers).
4. Calculate the embodied risk for each i (total risk).
5. Estimate total risks, indirect risks and risk multipliers for each value of i.

Propagation of risk through global supply chains

- Definition of embodied risk:
  - Embodied Risk (total risk) = Direct Risk + Indirect Risk
  - i,j : product, sector, company or country of interest

$$\mathbf{R}_i = \mathbf{r}_i \mathbf{X}_{ij} = \mathbf{r}_i \left(\mathbf{I} - \mathbf{A}_{ij} \right)^{-1} \mathbf{f}_i \qquad \forall ij$$

  - $\mathbf{R}_i$ is the embodied risk (or total factor risk) per unit output in sector i for each country. We can also write the Taylor series expansion to estimate risk at different tiers of the supply chain:

$$\mathbf{R}_i = \mathbf{r}_i \left(\mathbf{I} - \mathbf{A}_{ij} \right)^{-1} \mathbf{f}_i = \mathbf{r}_i \mathbf{I} \mathbf{f}_i + \mathbf{r}_i \mathbf{A}_{ij} \mathbf{f} + \mathbf{r}_i \mathbf{A}_{ij}{}^2 \mathbf{f} + \mathbf{r}_i \mathbf{A}_{ij}{}^3 \mathbf{f} + \mathbf{r}_i \mathbf{A}_{ij}{}^4 \mathbf{f} + \ldots.$$

Only through complexity can we understand simplicity

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