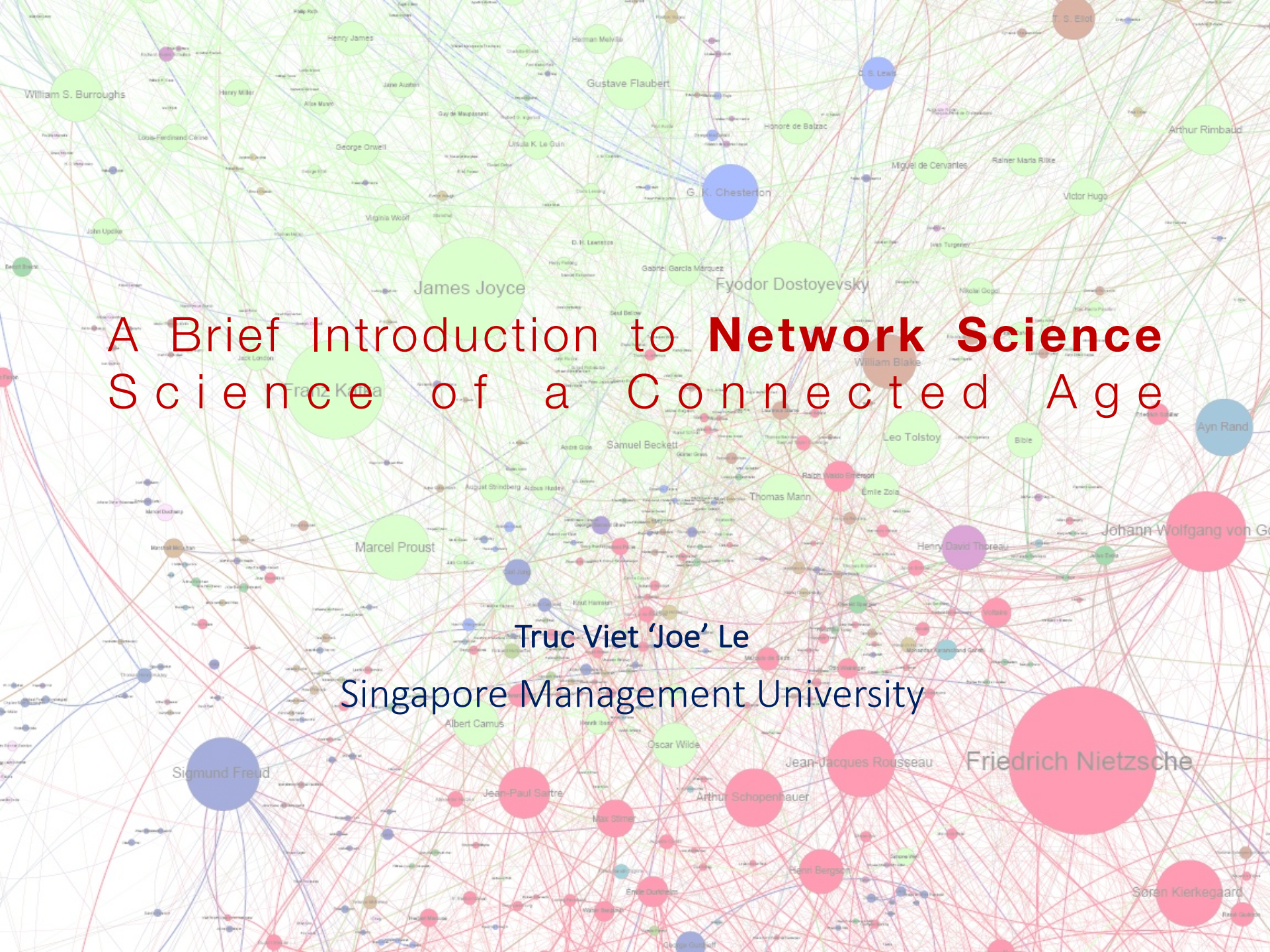




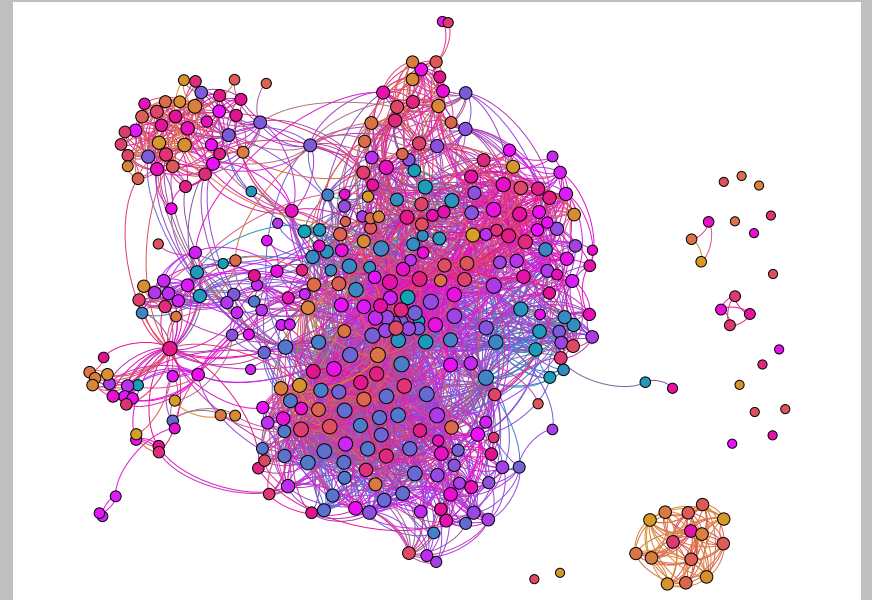
Science Café SG

www.facebook.com/groups/skskeptics

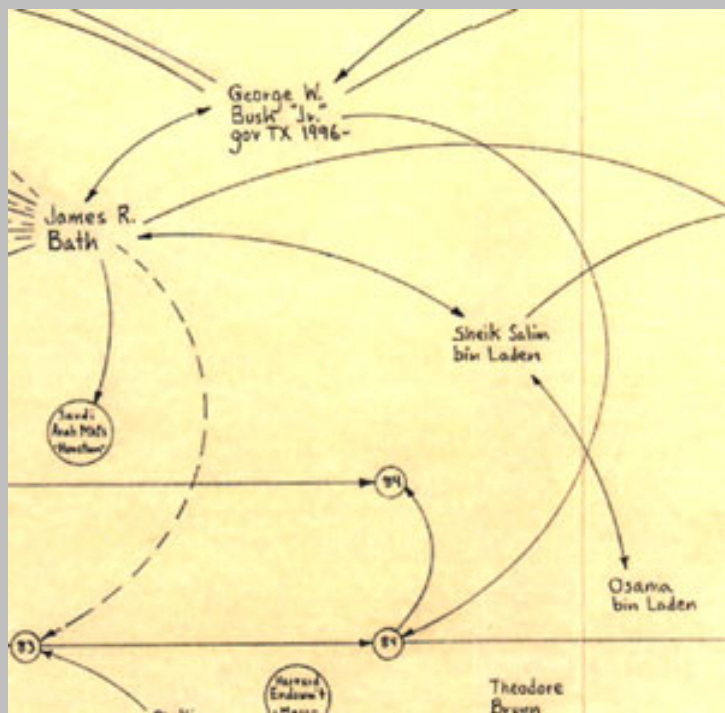


A Brief Introduction to **Network Science** Science of a Connected Age

Truc Viet 'Joe' Le
Singapore Management University



Models the **Complexity** of the **Real World**



Tracked and mapped global financial fiascos in the 1980s and 1990s from public sources such as news articles

“I happened to be in the Drawing Center when the Lombardi show was being installed and several consultants to the Dept. of Homeland Security came in to take a look. **They said they found the work revelatory**, not because the financial and political connections he mapped were new to them, but because Lombardi showed them an elegant way to **array disparate information and make sense of things**, which they thought might be useful to their security efforts. I didn’t know whether to find that response comforting or alarming, but I saw exactly what they meant.”

Michael Kimmelman

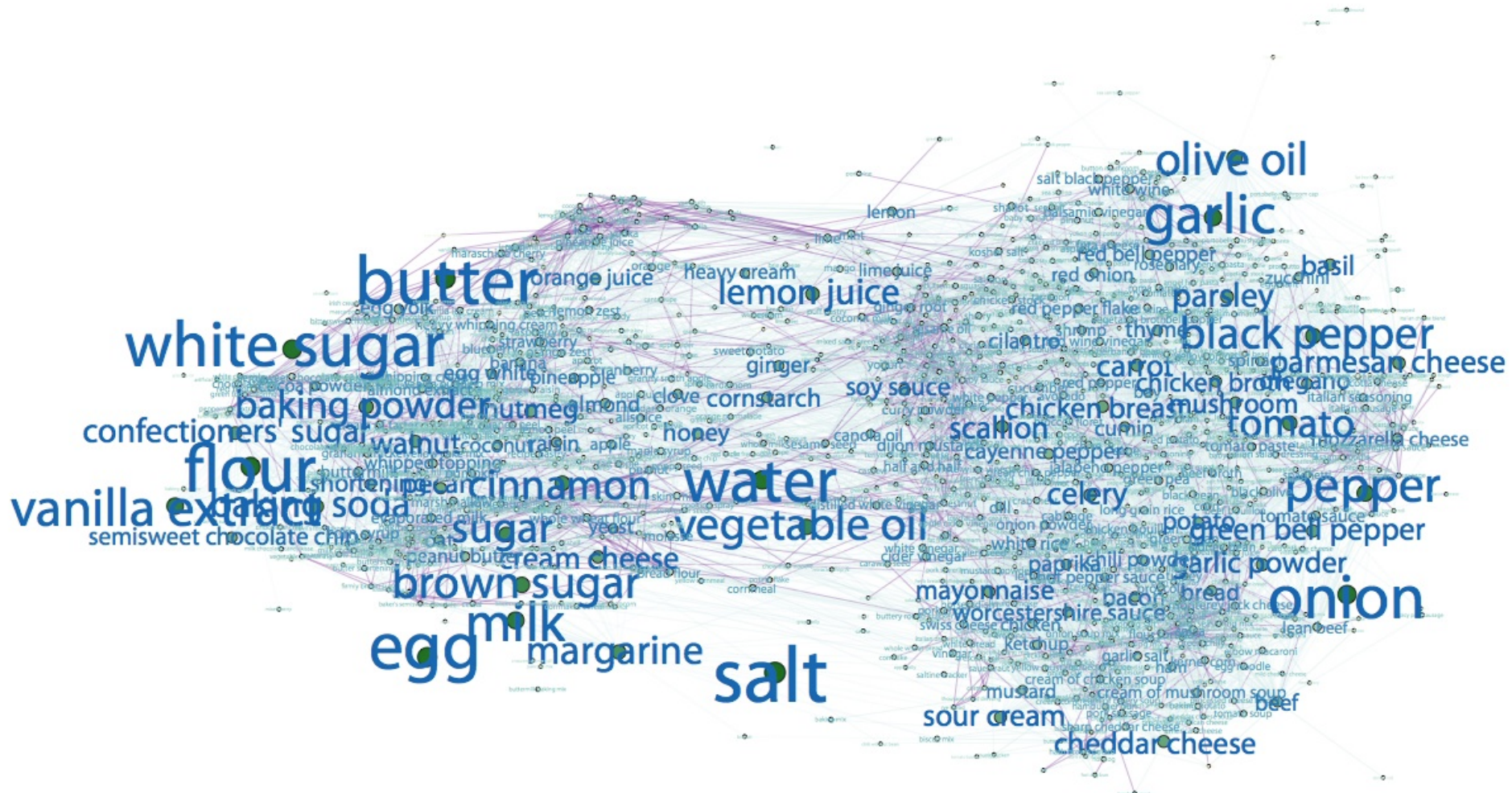
Webs Connecting the Power Brokers, the Money and the World

New York Times, Nov. 14, 2003

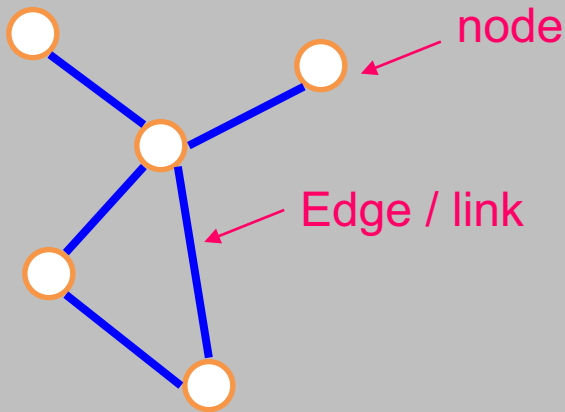
Political/Financial Networks Hand-drawn by **Mark Lombardi** [circa 1980s]



Global Connectivity – Mapping 58,288 Flight Routes by
Michael Markieta/Arup [2013]



The Ingredient Networks by **C. Y. Teng, Y. R. Lin, and Lada A. Adamic** [2012]



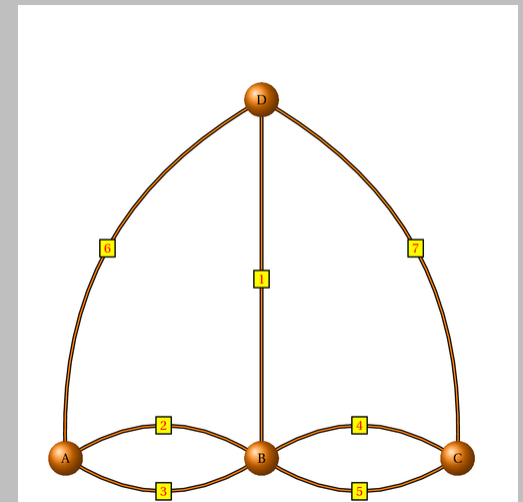
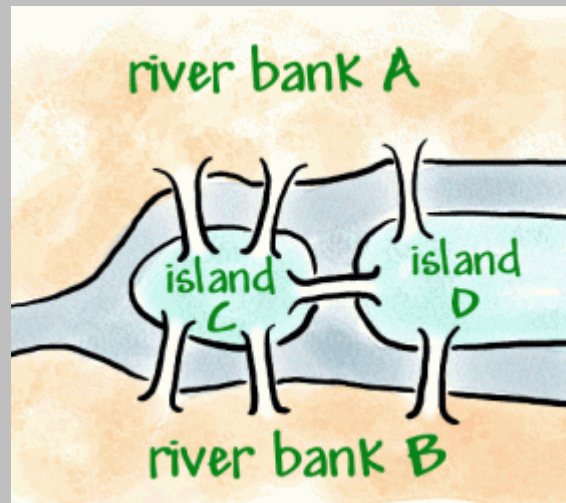
Networks are sets of nodes
connected by edges



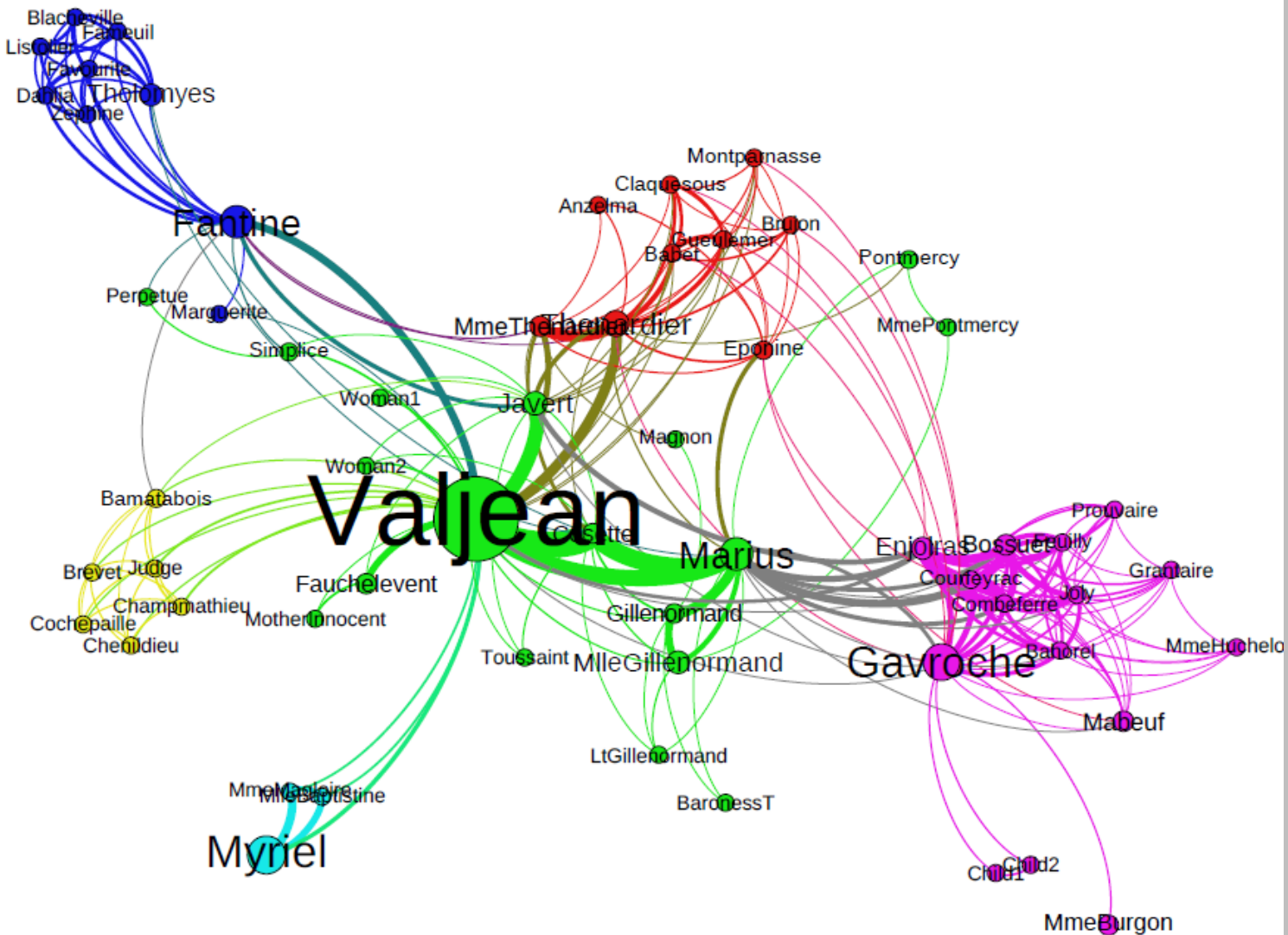
Leonard Euler (1707 – 1783)

“Network” = “Graph”

The Seven Bridges of Königsberg (Prussia, 1736)



What Are Networks?



Network Visualization of Relationships of Characters in *Les Misérables*



Instructions:

Given a target individual (stockbroker in Boston), pass the message to a person you correspond with who is “closest” to the target

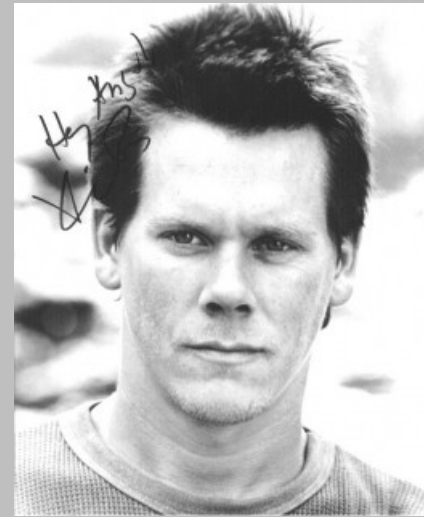
Outcome:

- 20% of initiated chains reached target
- Average chain length = **6.5**
- **“Six degrees of separation”**

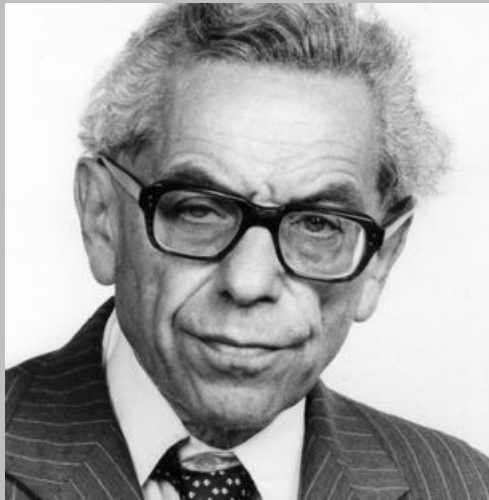
Small-World Experiment by **Stanley Milgram** [1967]

E-mail Experiment by Dodds, Muhamad, and Watts, *Science* (2003) – **Milgram's repeated**

- 18 targets
- 13 different countries
- 60,000+ participants
- 24,163 message chains
- 384 reached their targets
- Average path length is ~ 4



Bacon Number – the number of degrees of separation a given actor/actress has from Hollywood actor **Kevin Bacon**. Average Bacon number is ~ 6 .

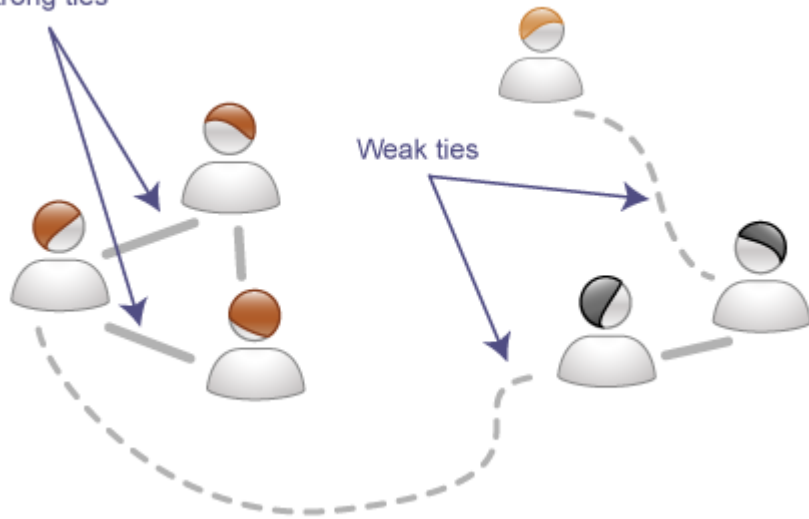


Erdos Number – the number of degrees of separation or “collaborative distance” a given scientist has from mathematician **Paul Erdos**. Average Erdos number is ~ 6 .

Is **6** a surprising number? In the 1960s? Today?

Six Degrees of Separation

Strong ties



Strong ties – close friends, share **redundant information** due to frequent contacts

Weak ties – casual acquaintances, no frequent exchange of info. → carry **novel, useful information** and facilitate the spread of innovations on networks

Granovetter's **Study of Job Hunters** in the Greater Boston area (1973):

- People tend to find out career opportunities through weak ties rather than strong ties
- → “Strength of weak ties”

Later studies echoed the **strength of weak ties**:

- Effective *social coordination* arises from weak ties
- Role of social media in **Tahrir Square** (2011)



Strength of Weak Ties by **Mark Granovetter** [1973]



Adam Smith's *The Wealth of Nations* (1776):

- The *division of labor* → collective task broken down into specialized subtasks
- The production of pins involves 20 independent tasks → division of labor generates *returns to specialization*
- Thus began the **Industrial Revolution**

In the 21st century, can we use **networks and data** to make an “inquiry into the wealth of nations”?

- How rich countries became rich?
- Why poor countries remain poor?
- What are the risks of the **middle income trap**?
- What are the economic **development patterns** of South Korea, Malaysia, and Chile? Why did one succeed more than the another?

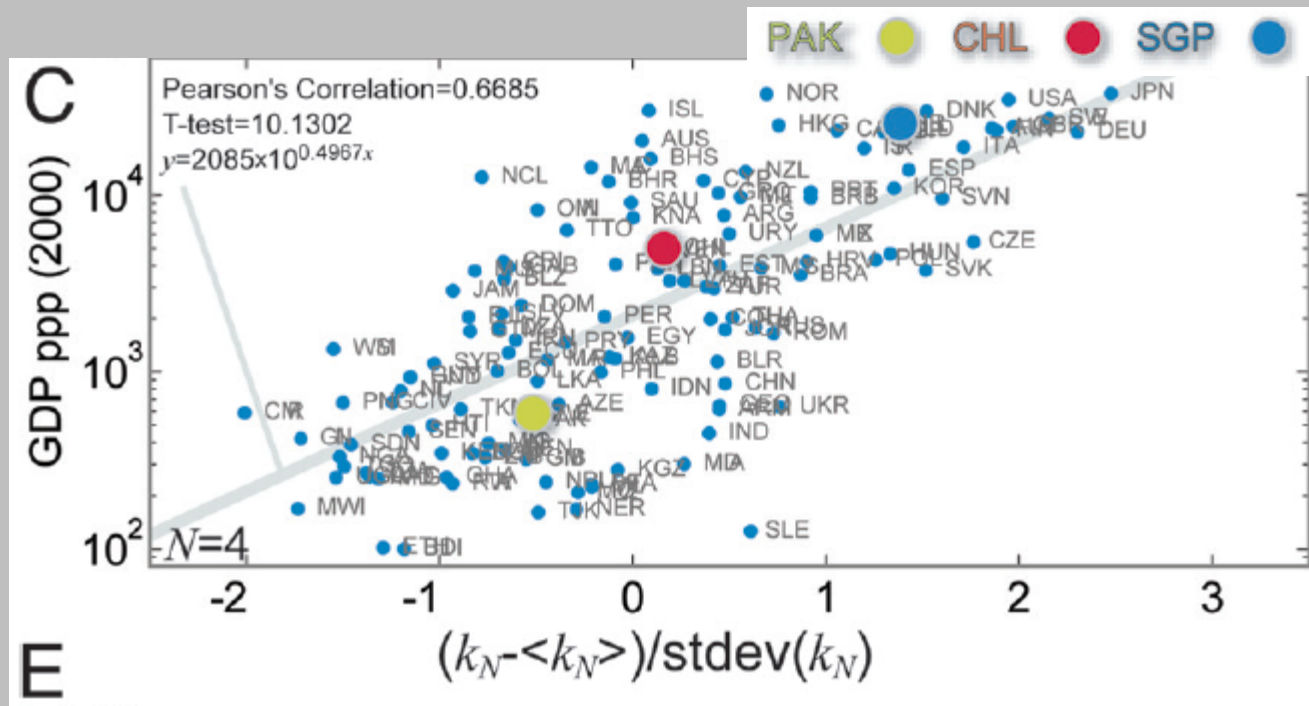
The Product Space by **C. A. Hildago *et al.*** [2007]

- The World is **Complex & Diverse**
- So is **Economic Development**

- Traditional economic development theory does not focus on diversity,

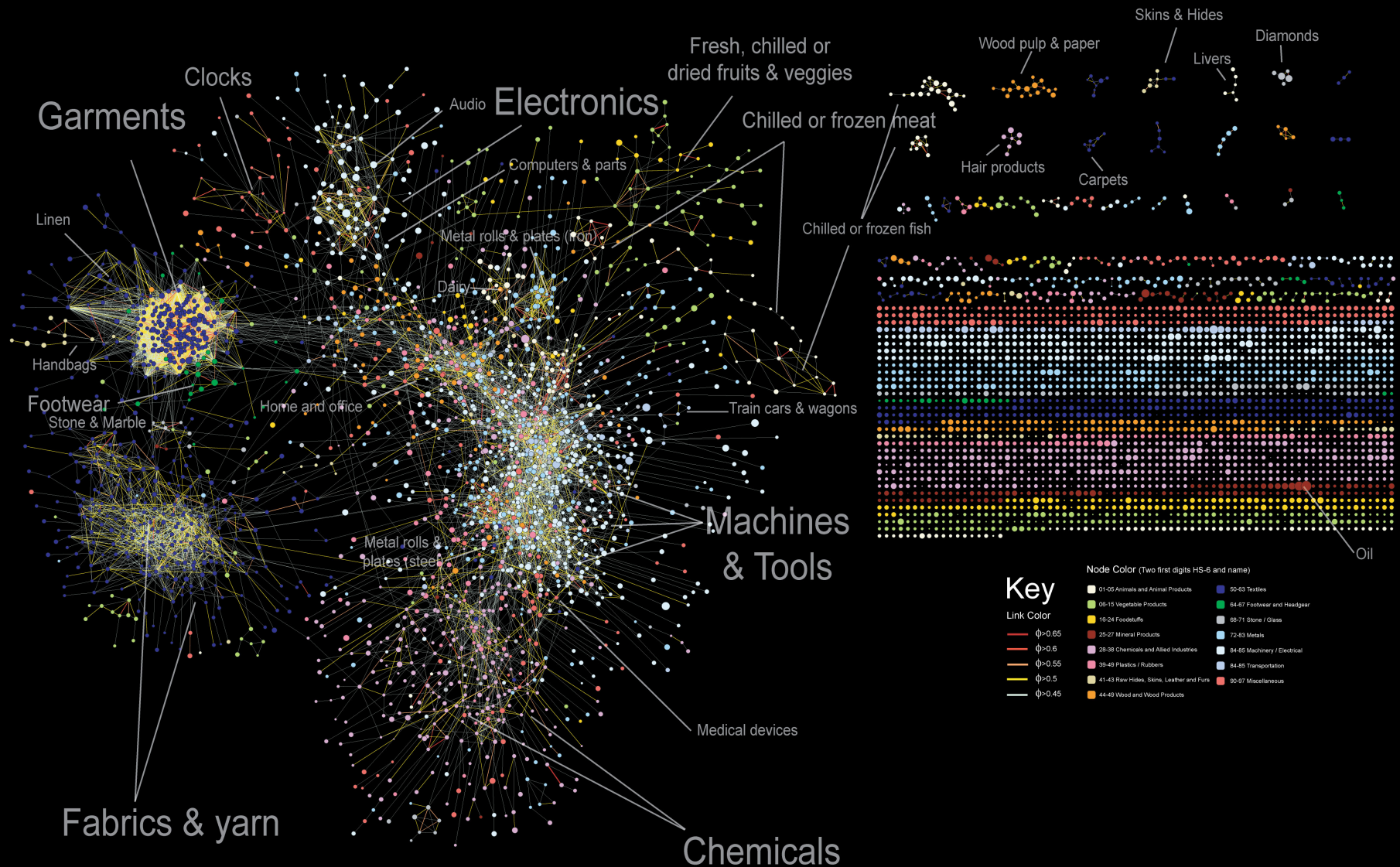
but rather on the aggregate level of output: $Y = F(K, L)$

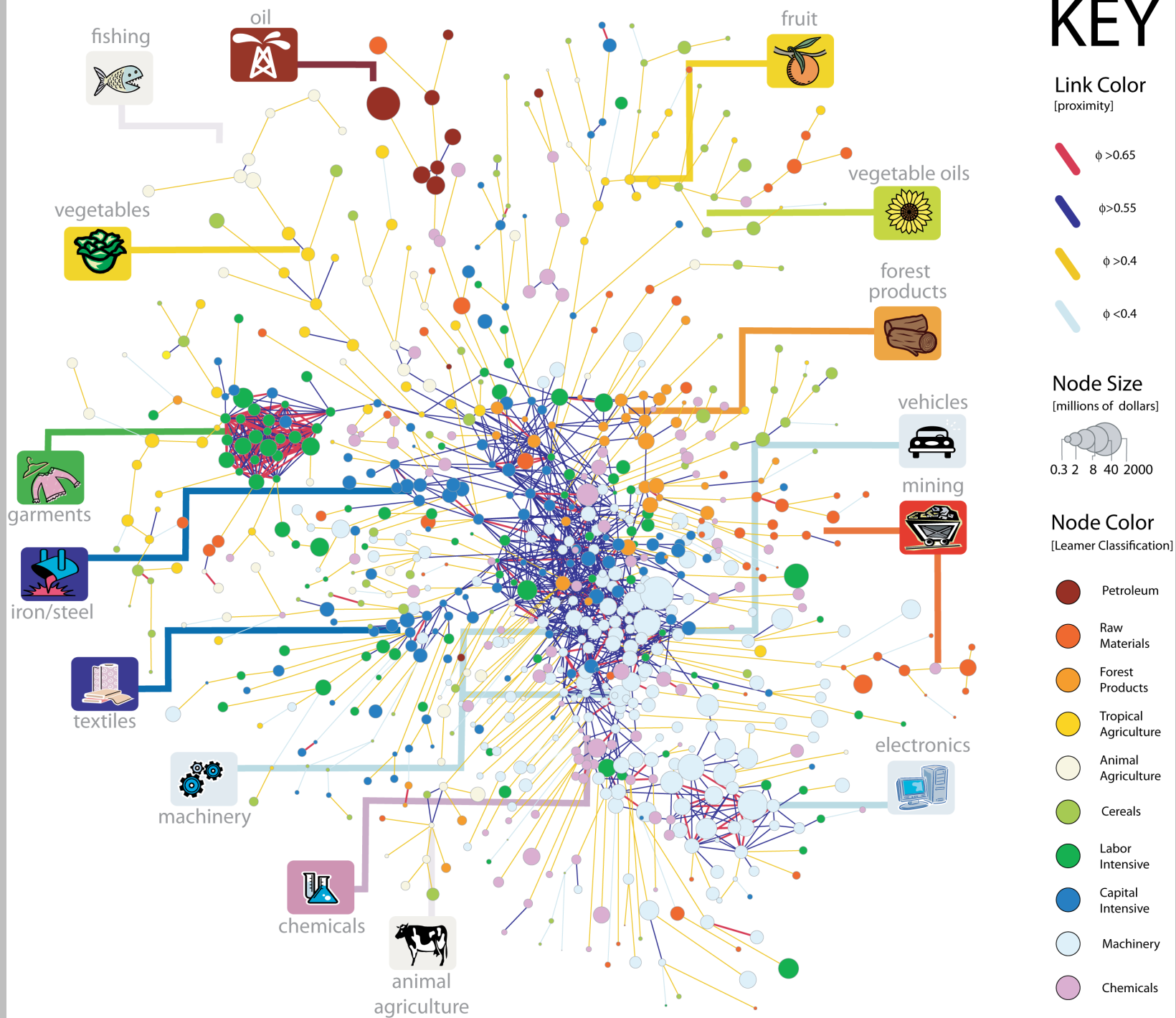
- Alternative theory of development that is not based on the aggregate level of demand, but on the **diversity of products** that a country exports
 - Products = Combination of **capabilities**
 - **Diversity of capabilities** → How many capabilities does a country have?



The **Product Space** graph is a network representation of products that require similar capabilities. **Products** are **nodes**. **Edges** connect **products** that **require similar capabilities**.

- Contains **1,000 product categories** with the highest global trade values
- Reveals **core – periphery structure** that corresponds to real export values





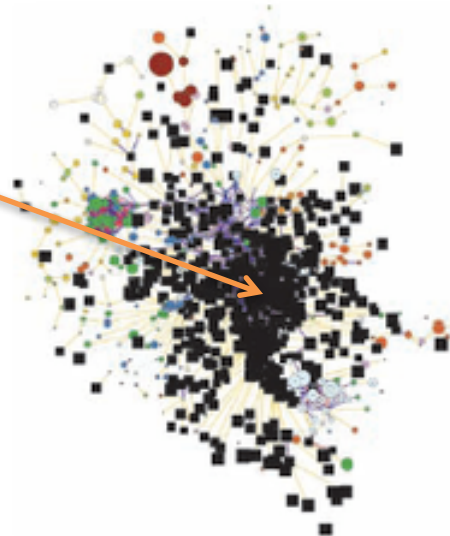
Products exported with **revealed comparative advantage (RCA)**



Industrialized Countries



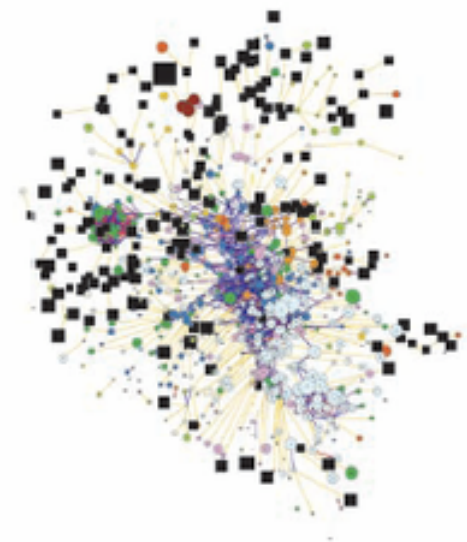
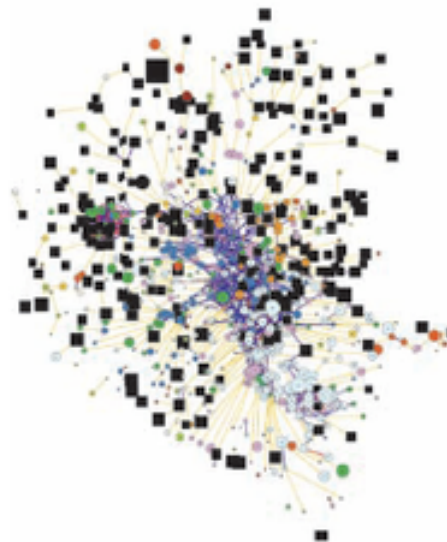
East Asia Pacific



Latin America
and
the Caribbean

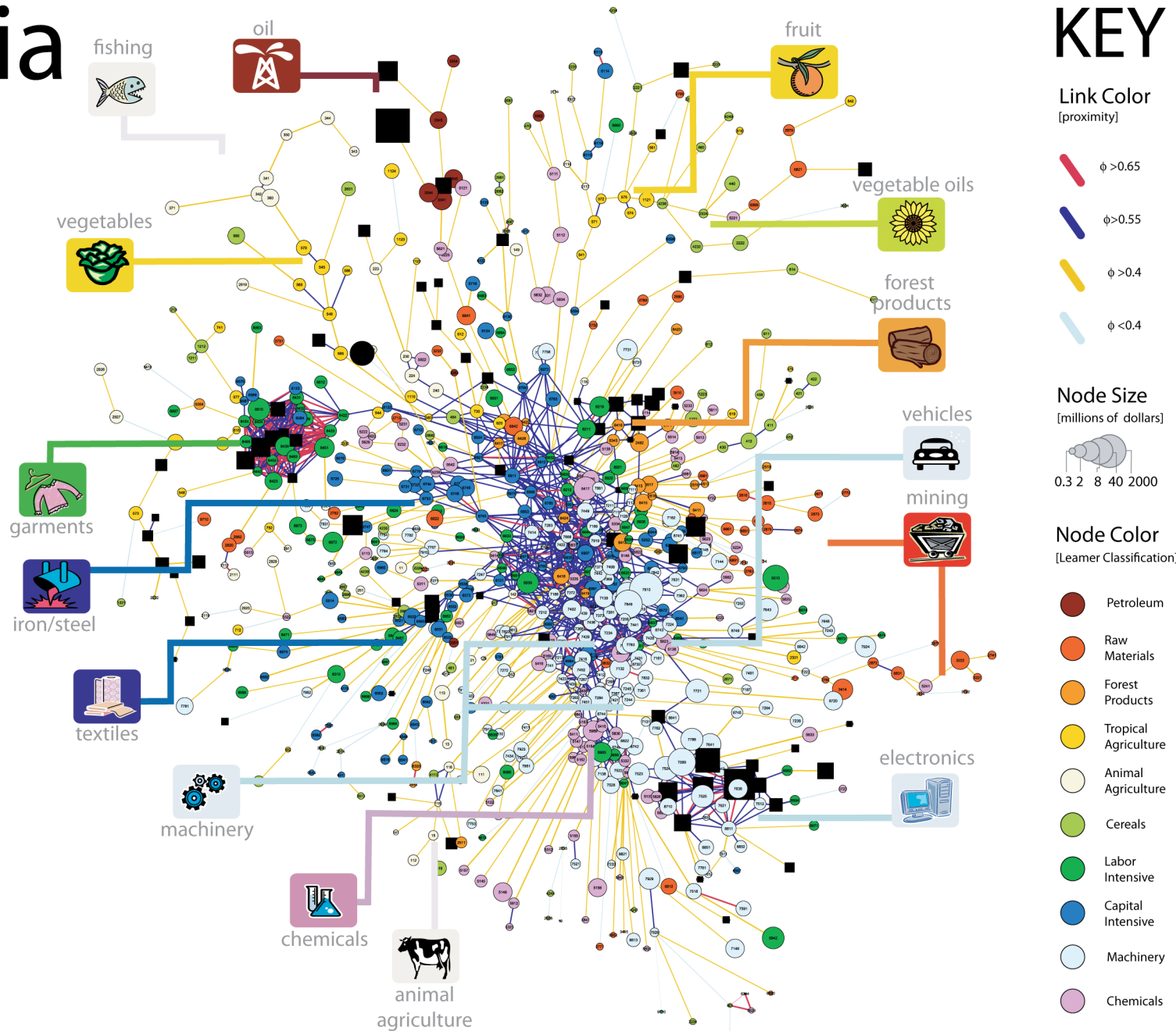


Sub-Saharan
Africa



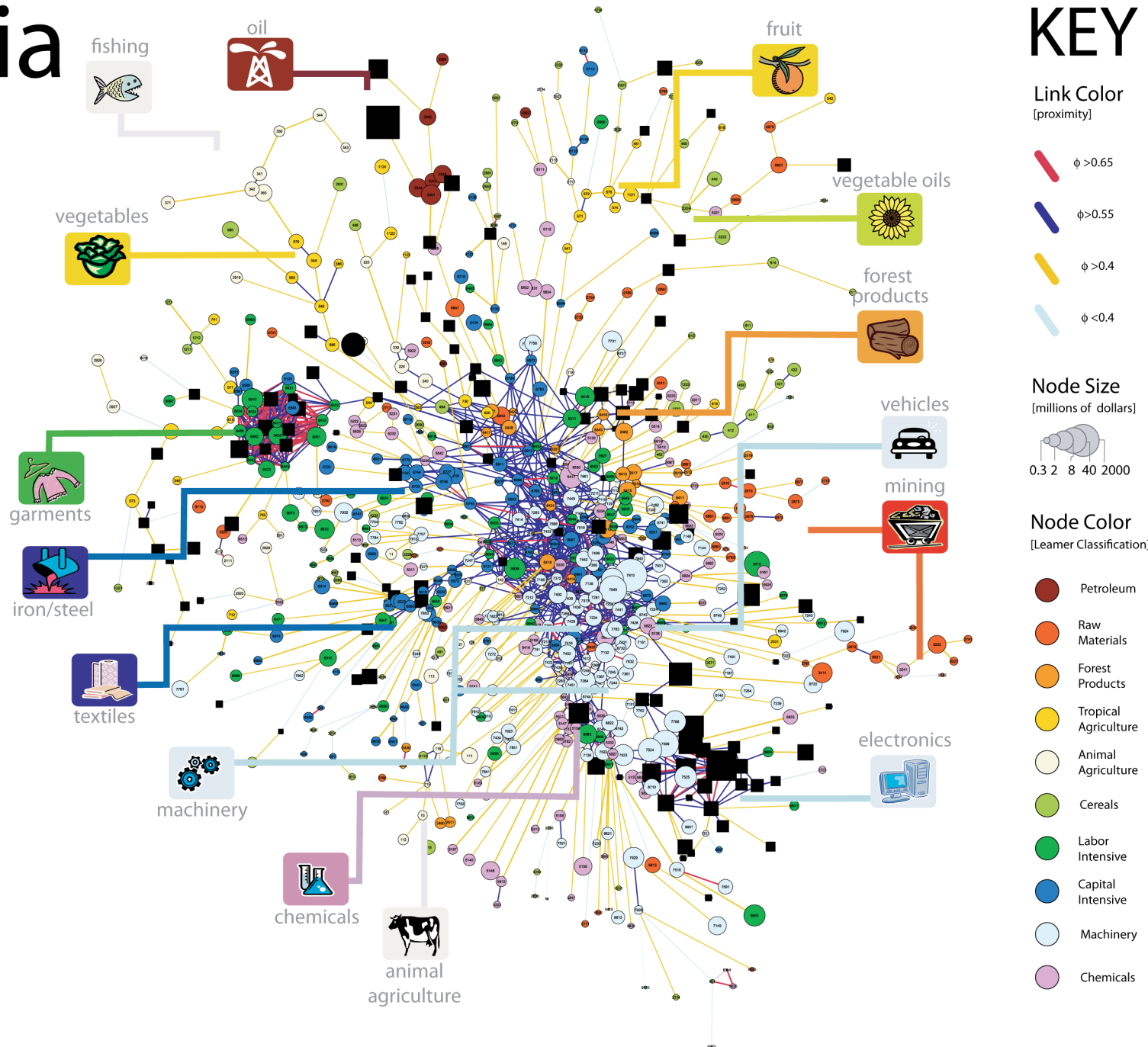
Malaysia (1985)

Products
exported
by Malaysia
with RCA>1



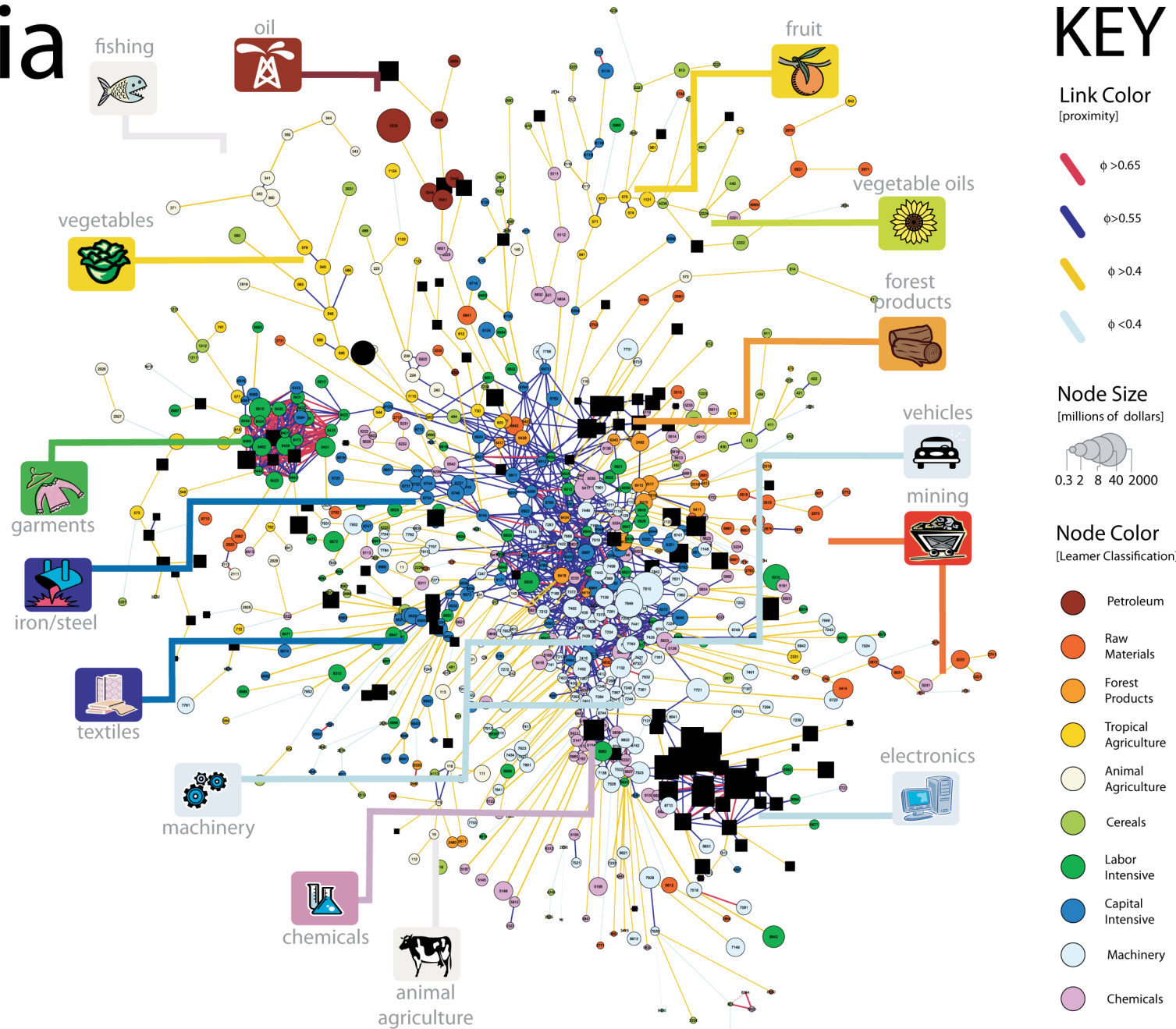
Malaysia (1990)

Products
exported
by Malaysia
with RCA>1



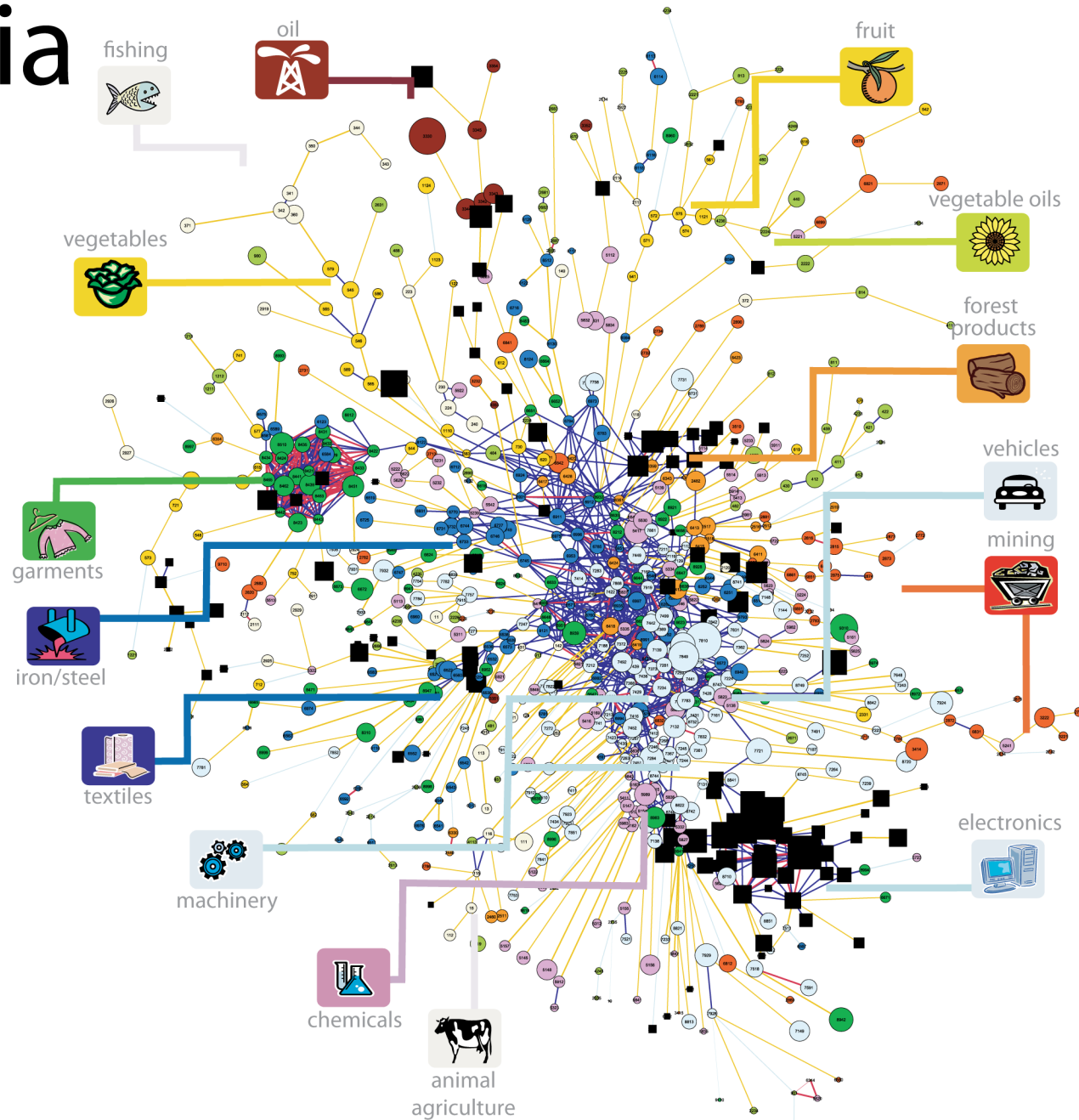
Malaysia (1995)

Products
exported
by Malaysia
with RCA>1



Malaysia (2000)

Products
exported
by Malaysia
with RCA>1

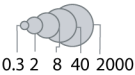


KEY

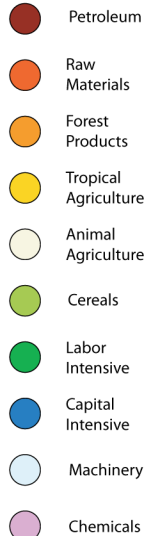
Link Color
[proximity]



Node Size
[millions of dollars]



Node Color
[Learner Classification]



So, What Is **Network Science**?

Truly **interdisciplinary** field of science

Attempts to **model** the **complexity** of the world through entities and their connections

Network **visualization** alone **reveals insights** that are otherwise non-trivial to see

Takes a **crude-look-at-the-whole** approach to model the **structures** and **relationships** of natural and societal phenomena

Is a **coming-of-age science** due to the increasingly connected world