Application of Graph Theory to International Trade Data

17.918
Behram Mistree
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1. Couple of notes:

   -I have put this lecture together, and if I have to, I can talk continuously for an hour on this subject...but I have a feeling that that wouldn't be particularly interesting or useful to all of you.

   -Or for that matter to me. The work that I am presenting is still being developed. Ask me questions, make comments, suggest ideas, disagree with me. Raise your hands or just plain interrupt me.

   -I have put in questions of my own as this presentation goes along. Think about them, answer them, etc.

NOTE:

- These slides were compiled as a presentation. Therefore, much key information was intended to be orally presented that does not appear in the slides. Please note that some of the numbers presented are fairly artificial: *they depend on the number of countries sampled and cutoffs determined by the author, but not included in the presentation.*
- In addition, some of the terminology described below has changed.
- Please contact bmistree@mit.edu if you have any comments or questions.

Things to Keep In Mind

- <u>International Relations</u>
  - Changes
  - Structure
- Adopt a <u>different perspective</u>

Before I really begin, I want to tell you that this talk may get a little technical.

Please don't worry. That's not all this class is going to be like. This is just an example to get you thinking about a few issues.

It's alright if you don't understand some of the upcoming mathematical nuances. But there are two things that I do want you to understand.

This workshop is designed to introduce students to different perspectives on international politics in the 21st century.

As such, it is important to understand something of the changes in international relations.

<u>Can anyone give me examples over the last 20 years..ask everyone to come up with one?</u>

<u>After they answer…make sure to ask how?</u>

<u>USSR dissolution</u>

<u>September 11</u>

<u>NAFTA</u>

<u>Formation of EU</u>

The other thing that I want you to keep in mind is the importance of adopting a different perspective.

Sometimes, it can take you places.

What Is the World?

- Simple Question
- But Important
  - If you Google "world", you get **2,860,000,000** hits.
  - "World" is a term that gets used a lot, and therefore it is important to understand.

A big part of this class is supposed to be

 Students' framing solutions to problems that they define.

 This presentation is largely an example of what we're talking about.
 Personally, I started by asking the question, "What is the world?"

 It is a seemingly simple question.
  -But some of the most enduring discoveries have arisen from asking the simple questions.
    -Newton asked what is light? And arrived at a truly revolutionary place.
    -Descartes asked what is existence? And postulated the famous "Cogito ergo Sum"

Ask someone the same question.
Anyone else?

The World is A Network of Networks

- Countries are linked to other countries often in quantifiable ways:
  - Migration;
  - Investment;
  - Aid payments;
  - Troop Deployments; and
  - …

Here is how I answered that question.

Can anyone else think of any ways that countries are related?
  If someone says trade…."You stole my thunder".

Trade: Exports

- Relevance:

    Trade…

    - Forces cultures to interact;
    - Is a mode of communication for ideas; and
    - Is a mode of communication for technology.

    Visualization tool

0. Why is trade relevant in the world?

1. Tinker around with tool.

Give me a country name...and then select it.

Ask for countries to compare.

2. All this is based on data from the CIA World Factbook 2005.

   Before I begin with a further presentation of some of the findings, now seems like a good time to point out that a lot of this work draws on a variety of disciplines. This project was only feasible because I had a good understanding of economics, computer science, and mathematics.

   We've taken a look at the class list, and know that a lot of you represent a lot of different areas. And that's fantastic.
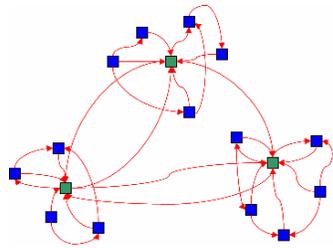   A lot of the interesting questions in the next few years
    -including the internet's governance;
    -infrastructure development; and
    -all manner of other quandries
are at the intersection of a lot of different disciplines.

Trade: Exports

- Visually, we might be getting a better idea of what is happening.
  - Visualizations can be important.
  - For instance, compare the more graphical display (bottom left) to the adjacency matrix (bottom right).

Example Adjacency Matrix For Export Data

Country	A	B	C	D	E
A	-	21,311	0	345,124	111
B	0	-	11,428	33,940	0
C	23,667	1,593	-	11,700	79,341
D	45,012	94,210	18,346	-	3,132
E	13,620	0	21,521	0	-

What are the benefits of the visualization program that I just showed off? (Rhetorical)

Next Step: Quantify Patterns and Trends

- Political <u>Science</u> as <u>science</u>:
    - We need ways to quantify what we are seeing.
    - Turn to mathematics; specifically graph theory.

<u>Can anyone describe to me what they just saw in that visualization program?</u>

It would be tough…you'd use words that might mean something to you that they don't to someone else.

Sciences (including the social sciences) try to get around that problem by quantifying, measuring, and metricizing.

Primer in Graph Theory

- Relatively new discipline
  - Developed by Erdos and Remyi in 1960s
- Applied to disciplines ranging from sociology to biology to computer science.
  - Society: Six Degrees of Separation (Milgram).
  - Study of brains: *C. Elegans (Barabasi, et al.)*.
  - Internet Average 19 Degrees of Separation (Barabasi).

1. Just a basic primer in graph theory If you want, I can give you more interesting readings at the end of class.

2. Can tell a few interesting stories about Erdos if I want.

3. Some folks will tell you that it goes all the way back to Euler...but for the most part, it only really got going in the 1960s

4. Take a look for a while at your handout describing some of the metrics of graph theory.

Graph Theory Applied to International Export Data

- From 1962-2004, for studied countries we observed an average **average degree of separation of 2.18** (rounded).
  - In any year, if I were to randomly select two countries, I would expect them to share at least one trade partner.
  - World is becoming *more interlinked* through trade.

1. The focus of this class is on

   changing international relations

   opening new channels of communication and new potentials for democratization

   Please note that these numbers are fairly artificial.

   They depend on the number of countries sampled

   and cutoffs determined by the author,

   but not included.

The graph at the bottom of this slide shows a very interesting trend. The world seems to be becoming more interdependent.

  New channels may be opening.

2. The blip upwards in 2004 there, I believe is due to the fact that there was a lot of data unavailable in 2004. (The number of countries sampled went from something like 150 to 77.)

Someone tell me what this might mean in any discipline.

  Tell me what it means for a computer scientist.

  Tell me what it means for a manufacturer.

  What should an economist take away from such a message?

  What should a policy developer say about such a thing?

Consequences of Interdependency

- **Propagation for Economic Failure**
  - Development in South Africa will impact Greenland (South Africa trades with both China and Japan, both of whom are major trading partners with Greenland),
- **Policy Decisions**
  - Example: In 1912, Norman Angell argued that increasing economic interdependence would make wars more costly and therefore as levels of economic cooperation between countries increased, we should expect less war between countries.
- **Ideas are flowing**
  - Cultures are spreading, fusing, and interacting.

1. Think of the entire world as a giant series of dominoes. The collapse of a far off domino can significantly affect your own well being.

   Therefore, our result implies a profound intersection of global interests...Development in South Africa will impact Greenland
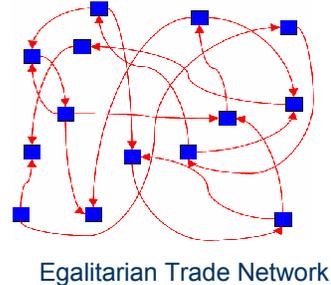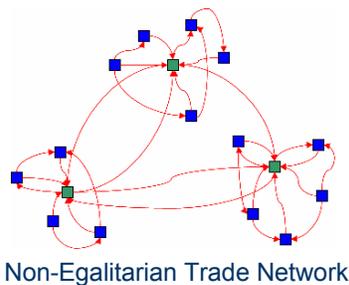
2. Can go to Dinsha for this if I want.

Such an intersection has very real policy ramifications.

3. And again, I cannot emphasize this enough: with trade, Ideas are flowing…cultures are interacting.

Structural Interpretations

- Essentially there are two structures that could have similar average degrees of separation.

Non-Egalitarian Trade Network   Egalitarian Trade Network

1. Average degree of separation tells us a lot about the nature of trade, and the interdependency that is beginning to permeate the world, but not a lot about the actual structure.

What do you think each such structure would imply?

 What questions and issues does each raise?

   -For a citizen of a hub?

   -For a citizen of a spoke?

   -For a member of the WTO?
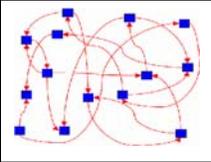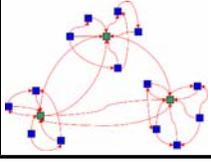
   -For a worker...

3. So what are the defining characteristics of each of these graphs.

   -There are some supernodes vs. all approximately similar degree.

   -Highly regionalized...Luckily, there are mathematical ways of testing stuff out like this.
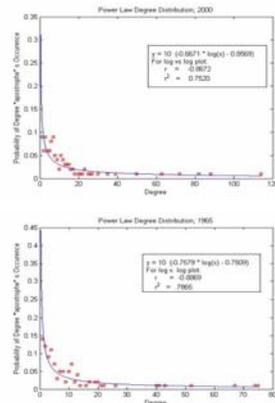
Structure Quantification

	Visual Structure	Average Degree of Separation	Average Clustering Coefficient	Degree Distribution
Egalitarian		< 10	< .3	Gaussian
Non-Egalitarian		< 10	> .5	Power-Law

At this point these numbers are fairly artificial.

  -They depend on the number of countries sampled.

  -They depend on the percentage cutoff that we are using for trade flows (for instance, we ignore $588 dollars going from Egypt to Sudan in 1989).

Degree Distribution Analysis

- Both graphs follow a Power-law:
  - We are dealing with a hub-spoke graph system (Newman)
  - Therefore, our trade network is Non-Egalitarian.

Data taken from the UN Commodity Trade Statistics Database Website (UN Comtrade).

1. The data does indeed follow a power-law.

2. Note: 1965 is missing USSR.

3. r is greater than .8 in absolute value for all sampled periods.
4. Can't really read r-values from screen…it's too small.

Clustering Coefficient Analysis

- The world's average clustering coefficient in 2000 was 0.57 (rounded)
  - In 2000, if Country A and Country B traded with Country C, there was a 57% chance Country A and Country B traded with each other.
  - For the most part, **countries traded in distinct groups**.

- This result also suggests a Non-Egalitarian trade network.

1. Say in 2000, that's the lowest clustering coefficient of any year studied.

2. Who can explain to me what I just said?

Brief Summary up to this Point

- Different perspective for viewing world
  - Choose a question and frame it in a different way.
- The world is becoming more (economically) interlinked
  - Cultures are spreading and interacting.
  - Policy ramifications.
- Where am I taking you?

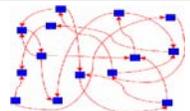Different perspective for viewing world

What are other examples that graph theory could be applied to?

-Migration

-Aid; etc.

Extensions: Globalization

- Project fundamentally emphasizes the need to categorize <u>different types of Globalization</u>.
  - *Egalitarian Globalization*
  - *Non-Egalitarian Globalization*

Globalization Type	Visual Structure	Average Degree of Separation	Average Clustering Coefficient	Degree Distribution
Egalitarian Globalization		< 10	< .3	Gaussian
Non-Egalitarian Globalization		< 10	> .5	Power-Law

A lot of folks when first reading data results like this would say, "Wow, Behram. That's the most amazing research I have ever seen. Your numbers would make a great metric for globalization."

However, they're only half right. Such a statement presupposes that we have already answered a very contentious question: What do you think globalization is?

  There is a distinct gap in the literature about the need for different types of globalization.

  This work suggests that there are different types of globalization.

Extensions: Paths for Economic Failure

- Lots of work in graph theory has been done on propagation of disease (Myers, et al.)
  - Fundamental: there are individuals who are in positions that link healthy and sick populations.
- With our metrics, we can identify a group of countries with low clustering coefficients that link disparate groups.

If you are dealing with an outbreak of disease, your first task is to contain the spread of the disease.

Similarly, if you are dealing with economic failure, your first task could be to contain it.

Let's go back to disease spread. Fundamental to the application of graph theory to disease spread is the notion that there are individuals who are in positions that link healthy and sick populations.

-Myers studied nurses travelling between different wards of a hospital.

Because we have a non-egalitarian structure for globalization, however, we see that there is a definite structure to how economic downturn or prosperity will affect another country. Turn back to previous slide…Point out pathway.

Myers did a study in a hospital

Go back to the domino example.

Extensions: Regulations

This slide is left blank for a reason. There are a million and one different policy options that would solve one million and one different problems.

  The trick is identifying what a problem is.

  Is it a problem that the world is becoming more interconnected?

  Is it a problem that it is the large super-nodal countries that seem to be most heavily involved?

  This presentation has been an objective lecture on what is currently happening in your world.

  But such an analysis is only the first step. I leave to you, both today and for the rest of this course the task of assigning value and judgement to the facts that we present. I urge you to think clearly, and bring to bear all facets of your personalities, disciplines, and knowledge.

Bibliography and References

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If you look through this bibliography, one thing that I want to emphasize is that there are

political scientists here.

There are economists.

But also, there are mathematicians.

There are biologists.

There are computer scientists. This is the direction that research is and should be moving.

Not only is the world getting more interlinked, but so are fields of study.

Bibliography and References

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