

APPLICATIONS OF NETWORK ANALYSIS ON ECONOMICS AND FINANCE

Nattapong Puttanapong, Ph.D.

Faculty of Economics, Thammasat University

Main Contents

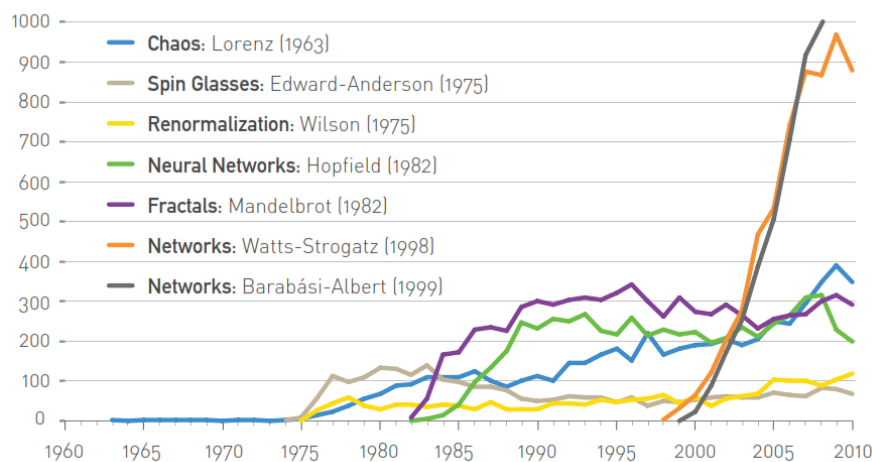
1. Introduction
2. Application on Interlocking Directorates
 - 2.1 Thailand's Stock Market
 - 2.2 Malaysia's Stock Market
3. Application on Macroeconomics
 - 3.1 International Trade
 - 3.2 US Economy
 - 3.2 Thai Economy

1. Introduction

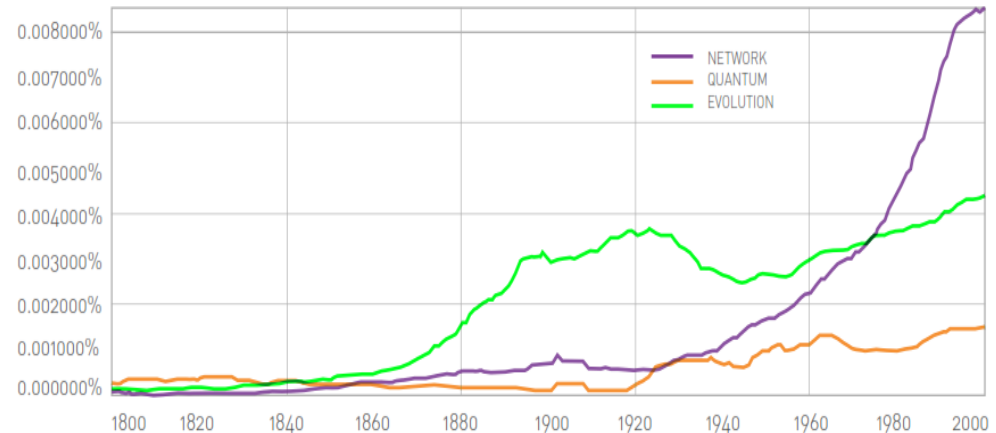
1.1 Random Graph Model

1.2 Small-World Model

1.Introduction



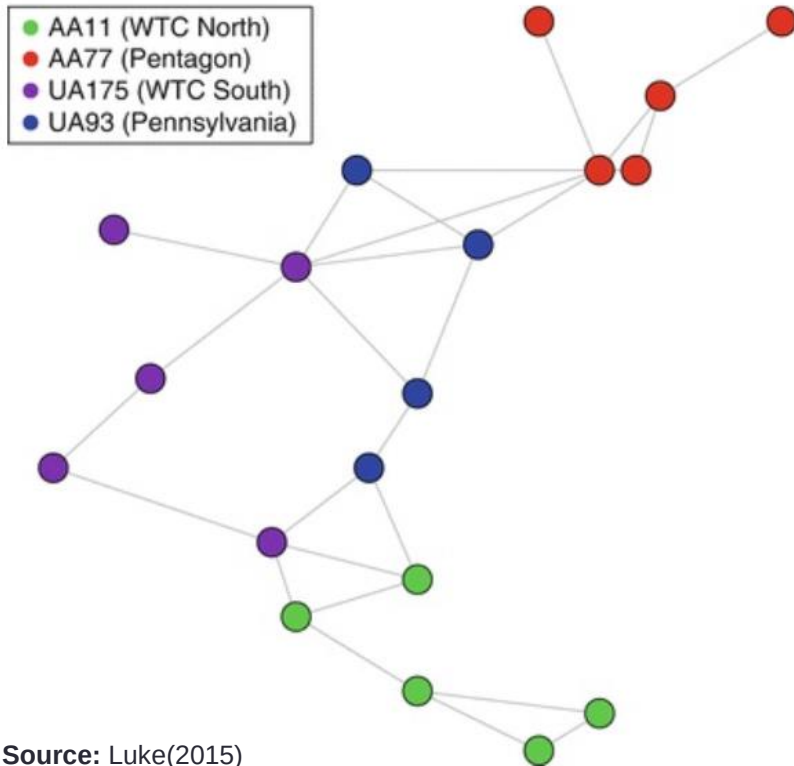
Source: Barabási (2016)



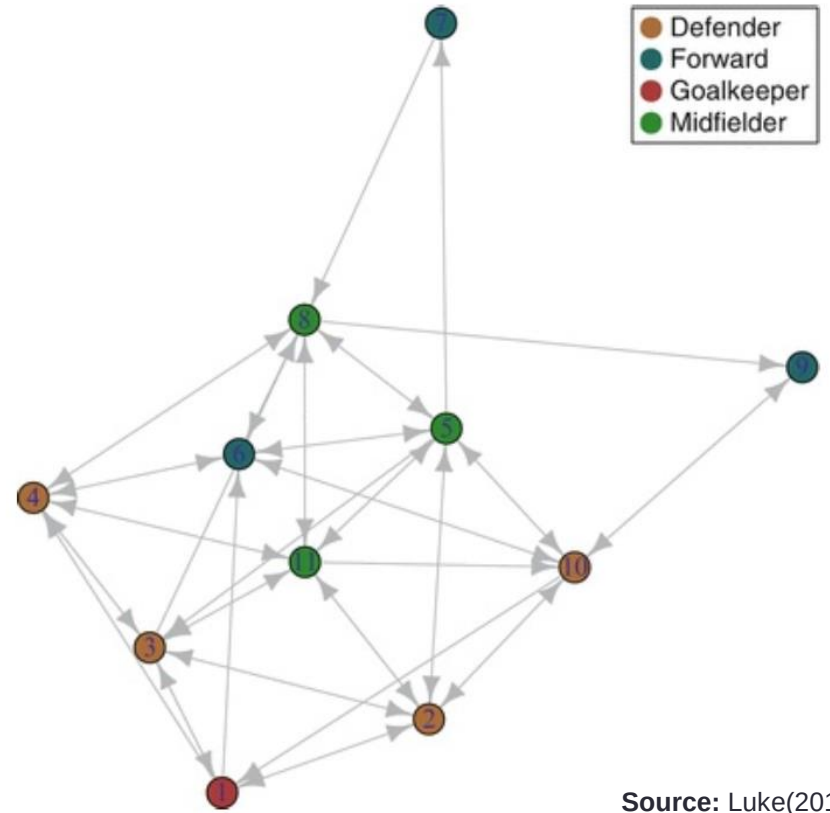
Source: Barabási (2016)

- The development of network analysis has been one of the most prominent fields of studies in the past 70 years.
- Barabási (2016) stated that when compared to other main areas of studies in science such as **quantum** and **artificial intelligence**, the **network analysis has surpassed** them in term of the **number of citations** and **the frequency of use of the words** in publications.
- Not only does the development of theories in network analysis provide the new foundation for **physic**, **chemistry**, **biology** and **engineering**, but it also broadens the knowledge in **social science**, **economics**, and even the **counterintelligence investigation** as documented by Lawton(2016).

Examples of Networks



Network of 9–11 hijackers

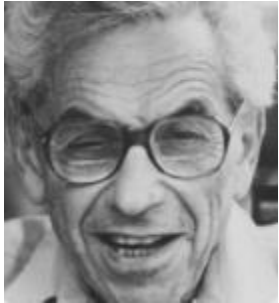


Network of Netherlands 2010 World Cup soccer team

1.1 Random Graph Model

- The **theoretical foundation** of network analysis has been initiated by **Erdős and Rényi (1959)**.
- Their work introduced the mathematical framework describing the quantitative characteristics of **network formulated by randomness** (i.e. the **random graph model**).
- Specifically, this theory enables **the prediction** of key indicators of **network's properties** such as:
 - the numbers of linkages
 - the average length of all paths
 - the diameter of the network

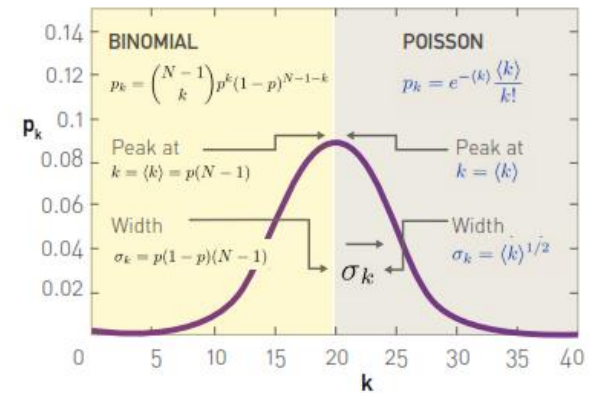
1.1 Random Graph Model



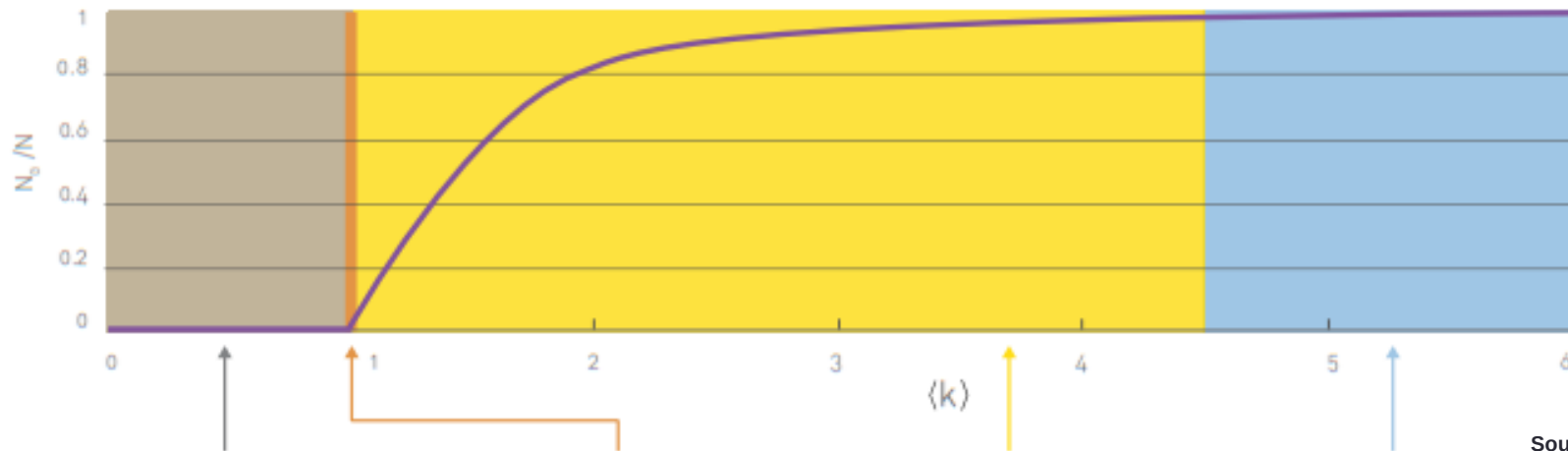
Pál Erdős
(1913-1996)



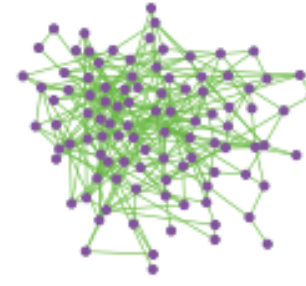
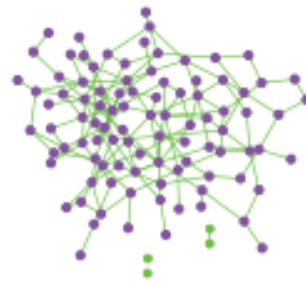
Alfréd Rényi
(1921-1970)



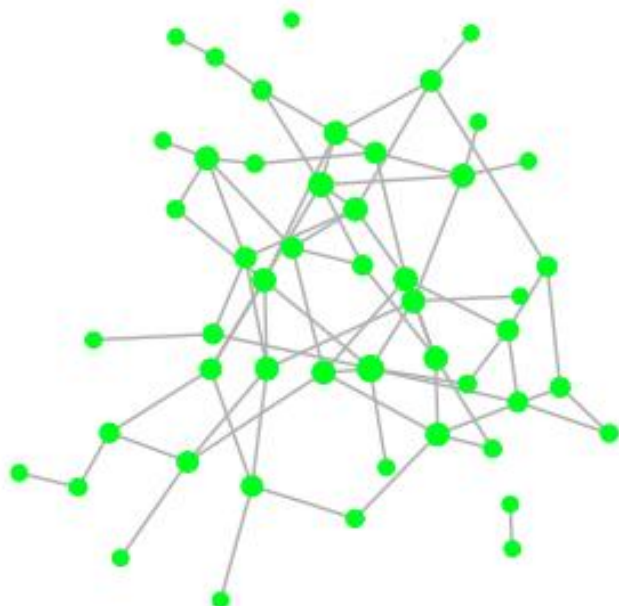
Source: Barabási (2016)



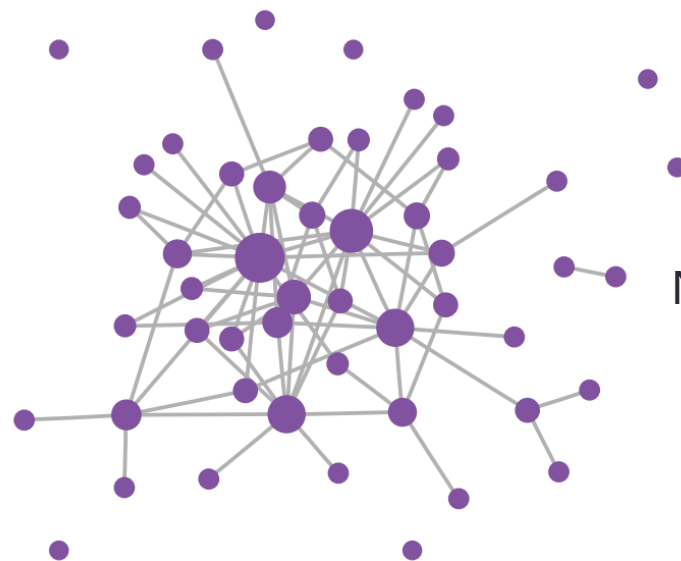
Source: Barabási (2016)



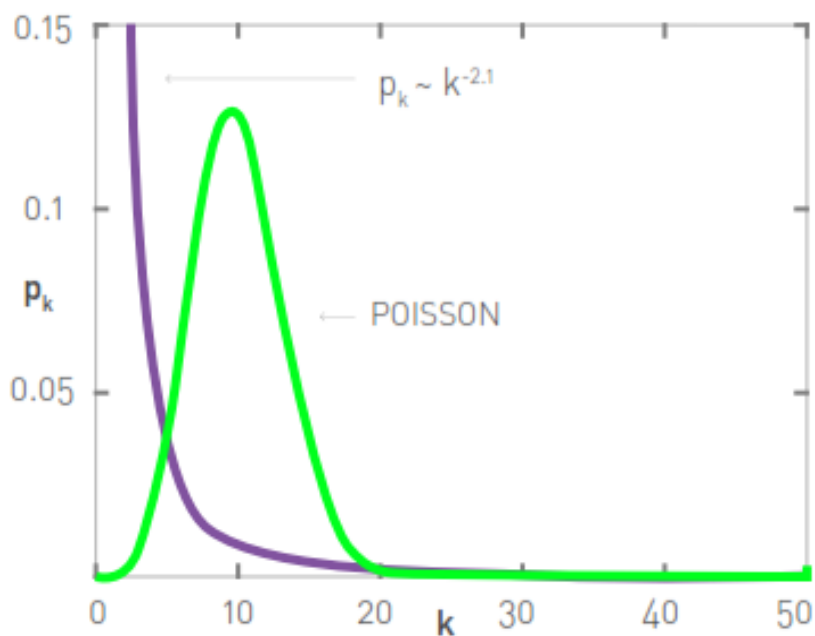
Network A



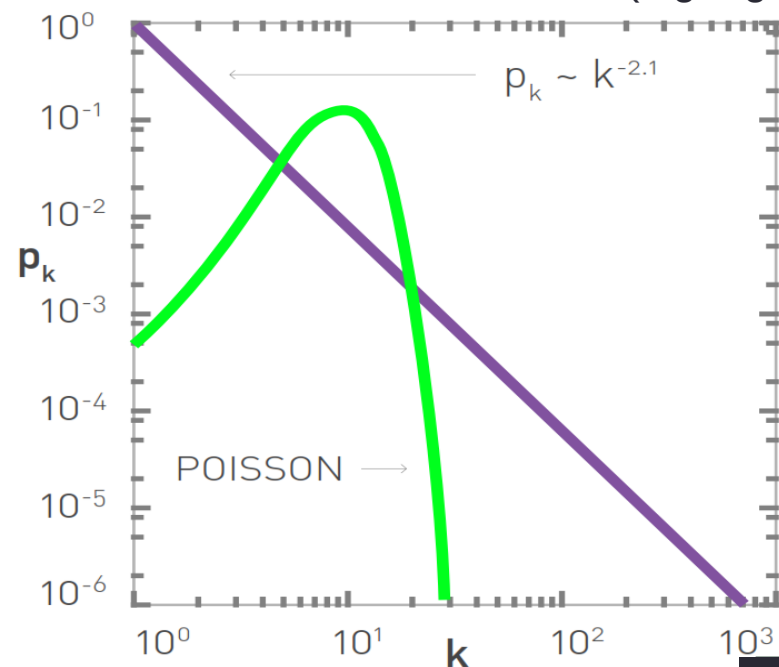
Network B



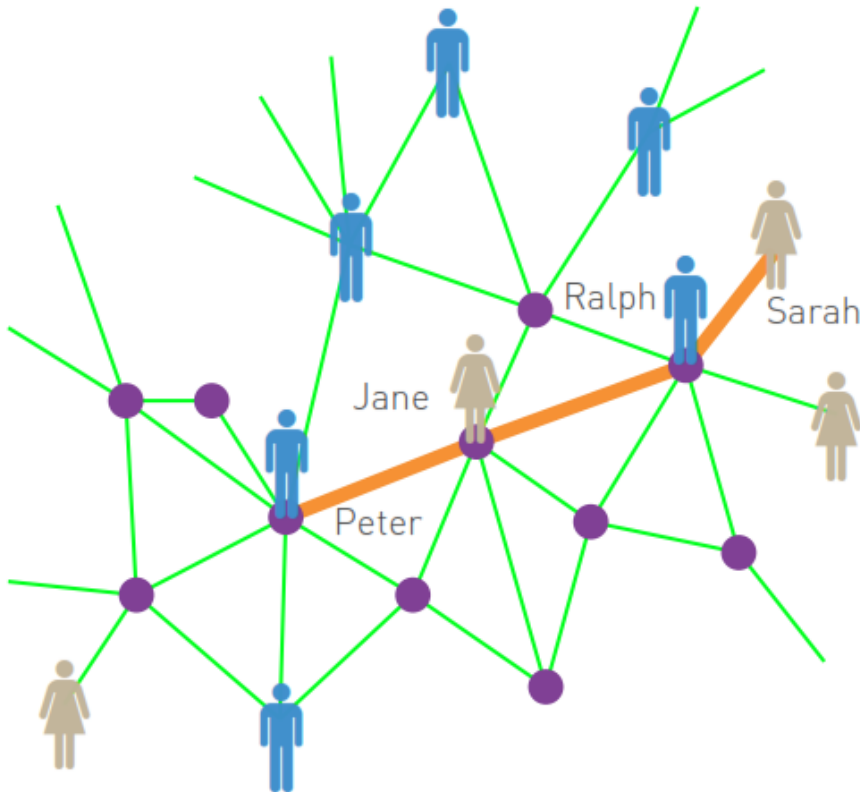
Distribution (linear plot)



Distribution (log-log plot)



1.2 Small-World Model



Source: Barabási (2016)

- Simultaneously, Ithiel de Sola Pool and Manfred Kochen initiated the mathematical framework in 1958.
- Later, de Sola Pool and Kochen (1978) explained the **special characteristic of human's society**.
- Their work proposes the idea that there is actually **a short path linking any pair of persons in the world** (i.e. the small world effect).

1.2 Small World Model (Cont'd)



Manfred Kochen



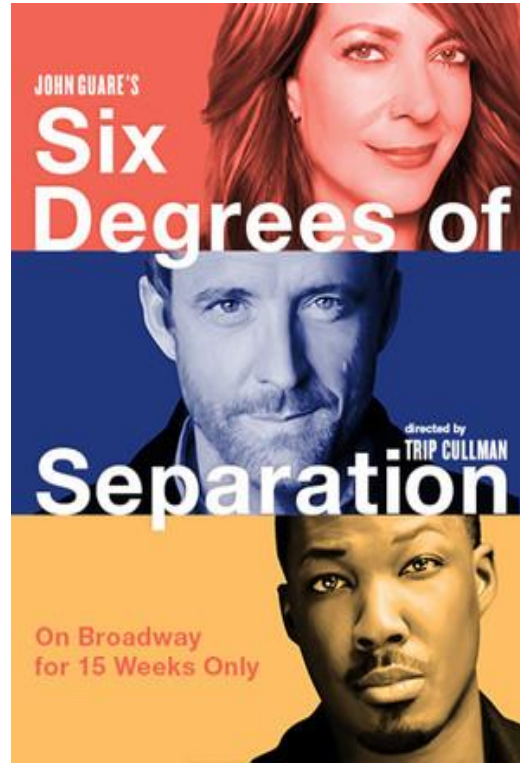
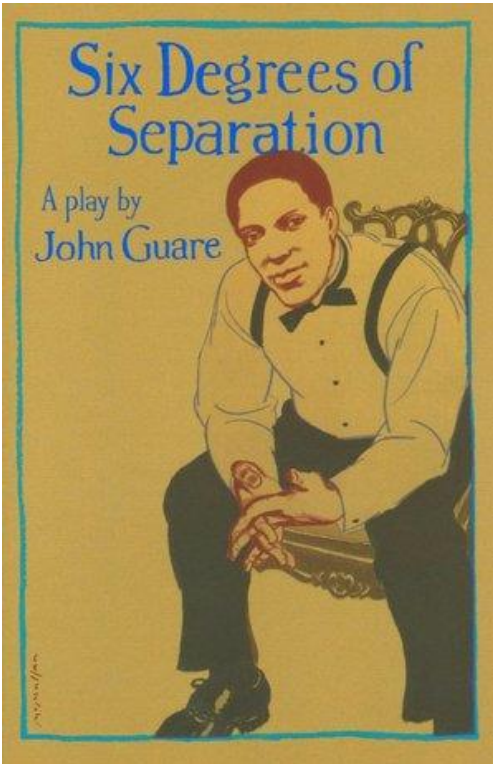
Ithiel de Sola Pool



Stanley Milgram

- Milgram(1967) documented the outcome of his **actual experiment** of small world effect using the **technique of randomly distributed mails**.
- His work, conducted in the US, has indicated that the **median of intermediates is 5.2**, implying that there are approximately the **maximum of 5-6 links connecting any pair of persons in the society**.

1.2 Small World Model (Cont'd)



- Guare(1991) applied the finding of Milgram(1967) as the fundamental of his famous Broadway play ‘six degrees of separation’, and this play’s title has become the popular phrase.

“Everybody on this planet is separated by only six other people. Six degrees of separation. Between us and everybody else on this planet. The president of the United States. A gondolier in Venice. ... I am bound to everyone on this planet by a trail of six people.”

Guare, 1991

1.2 Small World Model (cont'd)



Duncan J. Watts



Steven Strogatz

“The **average path length or the diameter** depends logarithmically on the system size. Hence, “small” means that the distance is proportional to **$\ln N$, rather than N or some power of N** ”

Source: Barabási (2016)

- Scientifically, Watts and Strogatz(1998) solidified the concept of small world effect through their breakthrough work.
- Their model provides the **mathematical framework** representing the **formulation and quantitative characteristics** of the small world phenomena.

2. Application on Interlocking Directorates

2.1 Thailand's Stock Market

2.2 Malaysia's Stock Market

2. Interlocking Directorate

- In finance, the pattern of **interlocking directorate** has been observed for many decades, and it triggered attentions from regulators and researchers.
- In addition, the development of methods in network analysis quantitatively **unveils two hidden networks**, which are the **affiliation among directors** and **the linkages among firms**.
- Particularly many literatures have documented the empirical evidence of **small-world pattern in stock markets** in cases of both developed and developing countries.
- These revealed outcomes shed light on the new insight of the connection among listed companies.
- Also they unveils the **new dimension of networks** that might **extend the fundamental concept of symmetric risk through interlocking directorate**.

2. Network Analysis of Interlocking Directorates

Counties	Related literatures
US	Battiston and Catanzaro (2004)
	Caldarelli and Catanzaro (2004)
	Davis et al. (2003)
	Strogatz (2001)
	Conyon and Muldon (2006)
	Caldarelli (2007)
	Robins and Alexander (2004)
	Kogut (2012)
UK	Conyon and Muldon (2006)
	Kogut (2012)
Australia	Robins and Alexander (2004)
Canada	Kogut (2012)
Italy	Battiston and Catanzaro (2004)
	Caldarelli and Catanzaro (2004)
	Caldarelli (2007)
	Kogut (2012)
Germany	Conyon and Muldon (2006)
	Kogut (2012)
The Netherlands and Switzerland	Kogut (2012)
	Heemskerk and Schnyder (2008)
Denmark, Norway and Sweden	Kogut (2012)
	Sinani et al. (2008)
South Africa	Durbach and Parker (2009)
South Korea	Kogut (2012)
	Nam and An (2017)
Poland	Sankowska and Siudak (2016)
Greek	Dimitrios and Vasileios (2015)
Spain, France, Brazil, Chile, Israel, Mexico and Taiwan	Kogut (2012)

Quantitative Characteristics of Networks

Main indicators of network's properties

- **Degree:** One of main properties of each node is degree. The magnitude of degree indicates **the number of links** to other nodes. If we define k_i as the degree of the i node and N is the number of total nodes, the total number of links (L) is denoted as:

$$L = \frac{1}{2} \sum_{i=1}^N k_i$$

- **Average Degree:** One of key indicators of the network is the average degree, denoted as $\langle k \rangle$. The formula for computing $\langle k \rangle$ is defined as:

$$\langle k \rangle = \frac{1}{N} \sum_{i=1}^N k_i = \frac{2L}{N}$$

- **Average Path Length:** The **average distance between all pairs** in a particular network is defined as the average path length, mathematically denoted as $\langle d \rangle$.

$$\langle d \rangle = \frac{1}{N(N-1)} \sum_{i,j=1 \text{ and } i \neq j}^N d_{i,j}$$

Quantitative Characteristics of Networks (cont'd)

- **Shortest Path:** The shortest path is the **route between two nodes which has the minimum distance**.
Alternatively, it is called Geodesic Path.
- **Diameter:** The **longest path between a pair of nodes** in the network is defined as the diameter (d_{max}). This indicator represents the width of the network.
- **Density:** The density is the **ratio of total number of links to the maximum number of potential links**. For the network with N node, the maximum possible number of links is $N(N-1)/2$. Therefore, the density(S) of the network is mathematically denoted as:

$$S = \frac{2L}{N(N-1)}$$

Quantitative Characteristics of Networks (cont'd)

- **Betweenness Centrality:** In addition to the number of links or the distance to others, one of important properties of a particular node is **its function of transmitting physical matter or information** to other nodes. Based on this concept, the Betweenness Centrality is the metric **quantifying the significance** of each node as **the key transmitter to the network**. Mathematically, this measure is based on the computation of number of sets of shortest paths to other nodes. Therefore, the highest Betweenness Centrality node has the maximum numbers of shortest paths to other nodes, enabling it to minimize time to transmit a substance or the information to other nodes with the maximum network coverage.

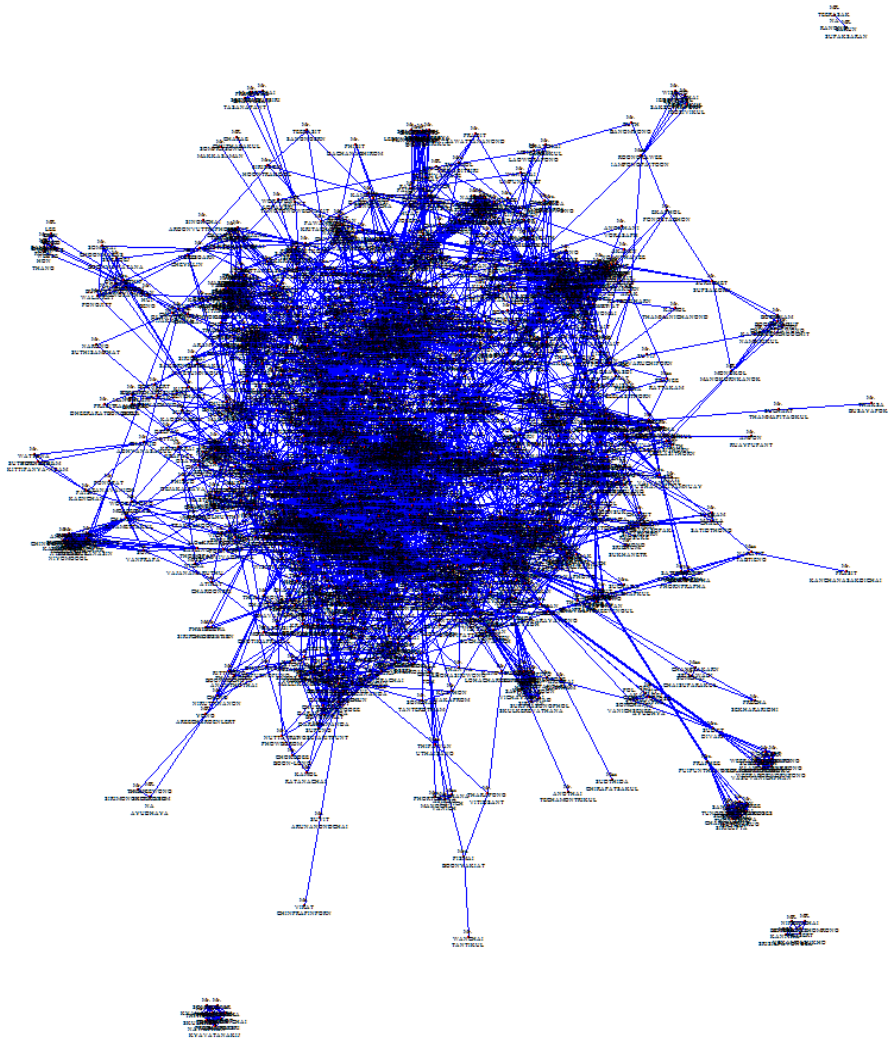
Quantitative Characteristics of Networks (cont'd)

- **Eigenvector Centrality:** the Eigenvector Centrality has been developed by **summing only linkages connected to important nodes**. Mathematically speaking, the computation is based on **the eigenvalue of the adjacency matrix**, which is the tabulated representation of nodes and linkages.

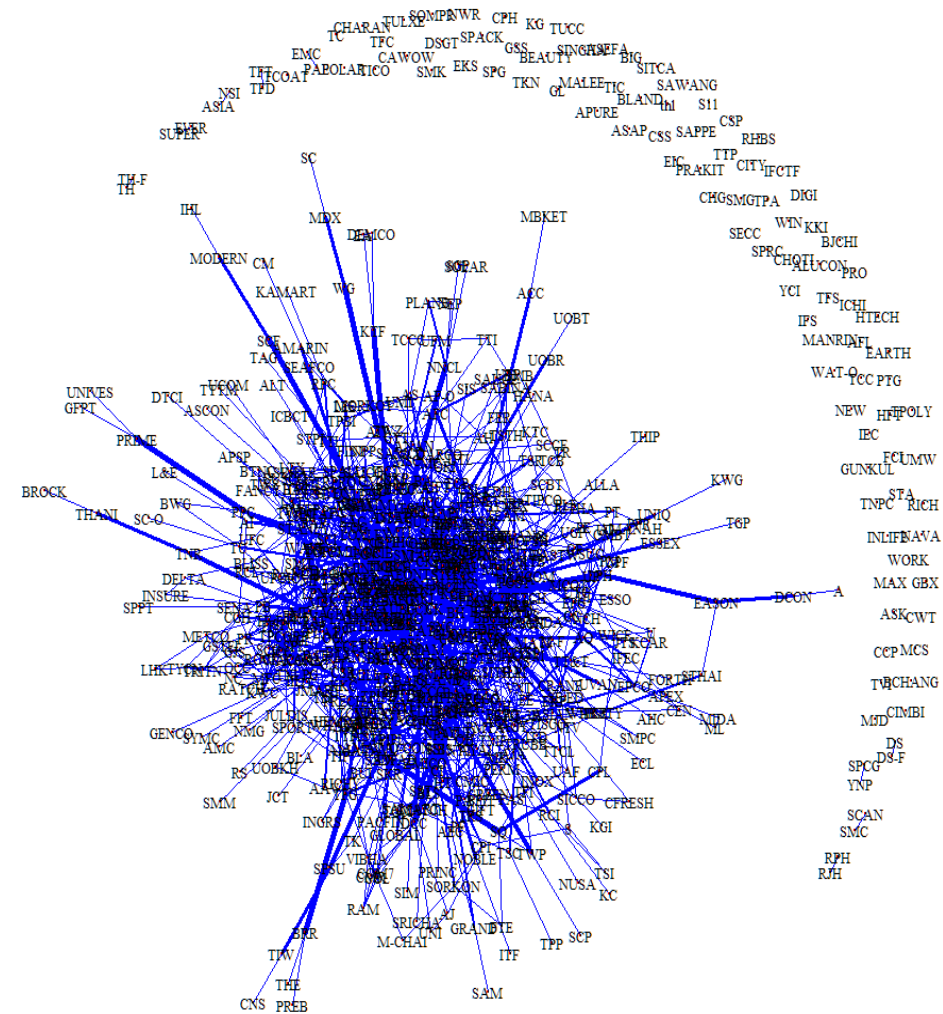
2.1 Thailand's Stock Market

2.1 Thailand's Stock Market

Network of directors (computationally formulated based on
Betweenness index of data of directors of 2016)



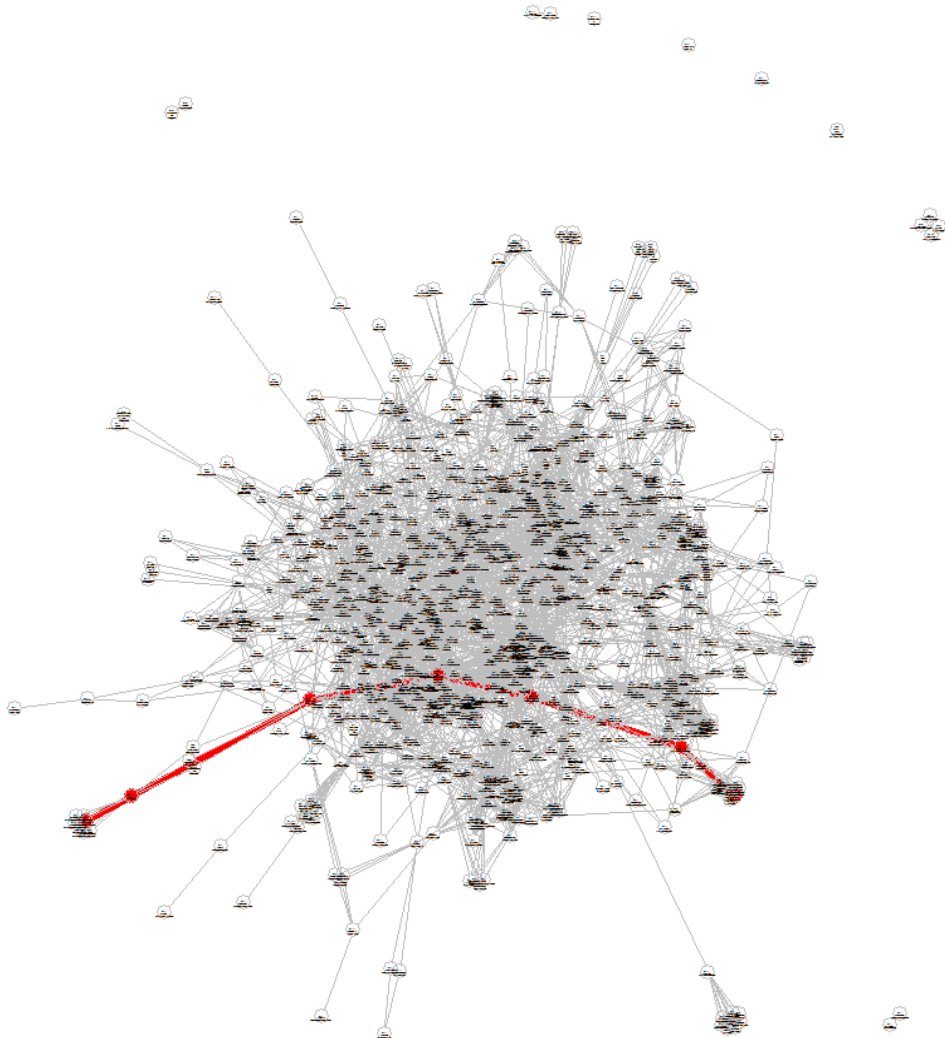
Network of boards of listed companies (computationally formulated based on Betweenness index of all boards in 2016)



2.1 Thailand's Stock Market

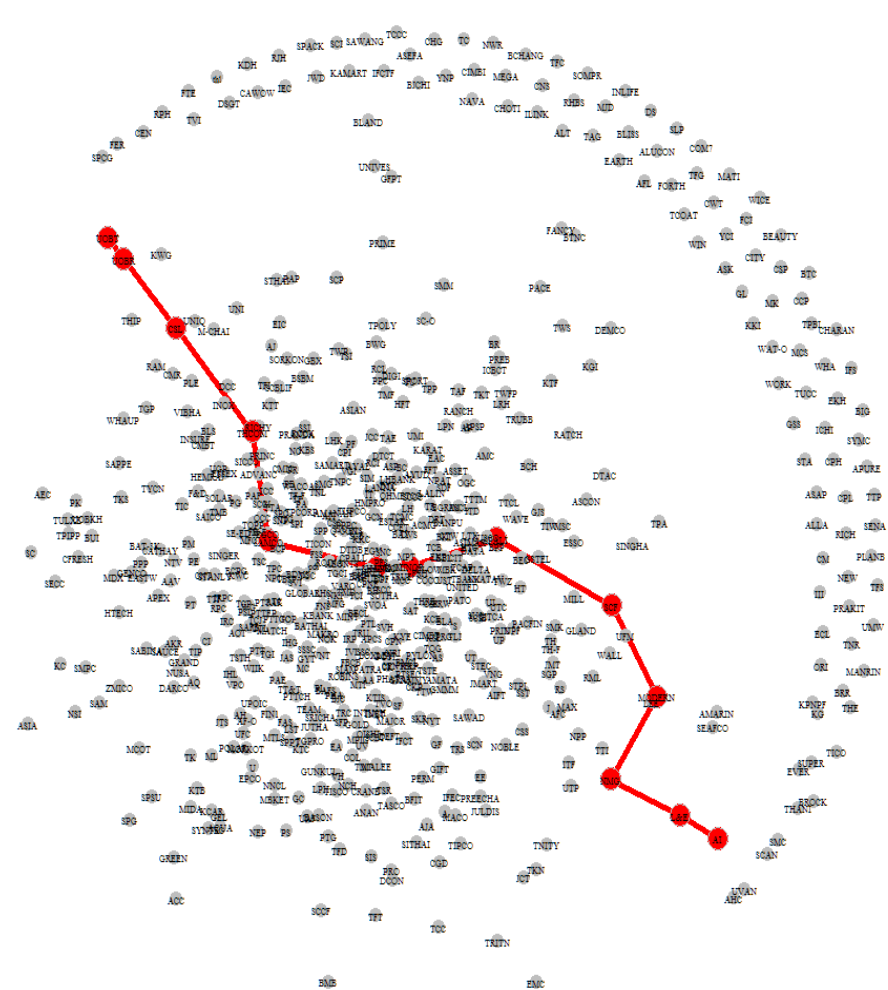
Diameter of network of directors

(computationally formulated based on Betweenness index of directors in 2016)



Diameter of network of listed companies

(computationally formulated based on Betweenness index of boards in 2016)



2.1 Thailand's Stock Market

Summary of key indicators of network's properties (the network of directors)

Year	Type of Network	Density	Standardized average degree	Closeness index	Eigen index	Diameter	Transitivity index	Average shortest path length
2012	Director Network	0.0082	0.0335	0.0017	0.9683	10.0000	0.6413	4.1056
2013	Director Network	0.0121	0.0395	0.0058	0.9364	9.0000	0.6001	3.8134
2014	Director Network	0.0119	0.0428	0.0061	0.9464	9.0000	0.5907	3.8469
2015	Director Network	0.0101	0.0404	0.0043	0.9368	11.0000	0.6385	3.9284
2016	Director Network	0.0117	0.0423	0.0049	0.9343	10.0000	0.6130	4.0310

The averages of shortest path length of all cases are lower than **6.0**. This result reveals the characteristics of **Six Degrees of Separation** in financial market, affirming the structure of human society in the connections among boards of directors.

2.1 Thailand's Stock Market

Summary of key indicators of network's properties
(the network of listed companies)

Year	Type of Network	Density	Standardized average degree	Closeness index	Eigen index	Diameter	Transitivity index	Average shortest path length
2012	Board Network	0.0081	0.0355	0.0026	0.9199	15.0000	0.3878	4.2342
2013	Board Network	0.0094	0.0349	0.0027	0.8993	15.0000	0.3835	3.9568
2014	Board Network	0.0094	0.0350	0.0028	0.9043	12.0000	0.3999	4.0182
2015	Board Network	0.0093	0.0340	0.0027	0.9061	11.0000	0.3950	3.9478
2016	Board Network	0.0083	0.0413	0.0026	0.9340	13.0000	0.3984	4.1595

Ranking of Betweenness index (network of directors)**

Betweenness index		Betweenness index		Betweenness index		Betweenness index		Betweenness index	
2012		2013		2014		2015		2016	
Mr. CHACKCHAI PANICHAPAT	0.039	Mr. MANU LEOPAIROTE	0.045	Mr. CHATCHAVAL JIAVANON	0.050	Mr. MANU LEOPAIROTE	0.046	Mr. MANU LEOPAIROTE	0.064
Mr. PRAKIT PRADIPASEN	0.037	Miss POTJANEE THANAVARANIT	0.036	Mr. MANU LEOPAIROTE	0.041	Mr. SUCHIN WANGLEE	0.043	Mr. PRASERT BUNSUMPUN	0.049
Mrs. CHANTRA PURNARIKSHA	0.033	Mr. SUCHIN WANGLEE	0.036	Mr. SUCHIN WANGLEE	0.040	Miss POTJANEE THANAVARANIT	0.037	Mr. SUCHIN WANGLEE	0.040
Mr. SUCHIN WANGLEE	0.032	Mr. CHATCHAVAL JIAVANON	0.036	Miss POTJANEE THANAVARANIT	0.037	Mr. CHATCHAVAL JIAVANON	0.036	Mr. ARSA SARASIN	0.038
Mr. WEERAWONG CHITTMITTRAPAP	0.031	Mr. PRASERT BUNSUMPUN	0.033	Mr. PRAKIT PRADIPASEN	0.032	Mr. PRAKIT PRADIPASEN	0.034	Mr. PRAKIT PRADIPASEN	0.036
Mr. MANU LEOPAIROTE	0.030	Mr. WISSANU KREA - NGAM	0.028	Mr. PRASERT BUNSUMPUN	0.031	Mr. WEERAWONG CHITTMITTRAPAP	0.033	Mr. RAWAT CHAMCHALERM	0.032
Mr. WISSANU KREA - NGAM	0.030	Mrs. NUALPHAN LAMSAM	0.028	Mr. SUVARN VALAISATHIEN	0.028	Mr. PRASERT BUNSUMPUN	0.032	Mr. VIRACH APHIMETEETAMRONG	0.031
MR. PONG SARASIN	0.029	Mr. PRAKIT PRADIPASEN	0.028	Mr. SIRI GANJARERNDDEE	0.026	Mr. SIRIPOL YODMUANGCHAROEN	0.027	Mr. SUVARN VALAISATHIEN	0.030
Mr. CHAI SOPHONPANICH	0.025	Mr. JOTI BHOKAVANIJ	0.025	Mr. SATIT CHANJAVANAKUL	0.024	Mr. ARSA SARASIN	0.026	Mr. CHAINOI PUANKOSOOM	0.026
Mr. CHATCHAVAL JIAVANON	0.025	Mrs. KULPATRA SIRODOM	0.025	Mr. CHAI SOPHONPANICH	0.023	Mr. CHAI SOPHONPANICH	0.024	Mr. CHATCHAVAL JIAVANON	0.026

** This is an outcome of scientific computation. With all best regards, the author has no intention of creating any negative consequences to all directors listed in this table.

Ranking of Betweenness index (network of boards of listed companies)

Betweenness index		Betweenness index		Betweenness index		Betweenness index		Betweenness index	
2012		2013		2014		2015		2016	
SSC	0.036	SCB	0.033	TRUE	0.031	TOC	0.032	SSC	0.044
SCC	0.032	MFC	0.030	THRE	0.029	DTC	0.032	DTC	0.043
KBANK	0.032	SCC	0.028	ERW	0.029	SCC	0.031	TOC	0.036
BH	0.030	LOXLEY	0.027	FBCB	0.028	SCB	0.029	MINOR	0.032
SAMCO	0.026	FBCB	0.027	SCB	0.027	ERW	0.029	SCC	0.031
LOXLEY	0.026	TRUE	0.026	LOXLEY	0.026	THRE	0.028	ERW	0.027
FBCB	0.025	BKI	0.024	SCC	0.025	TRUE	0.028	SPALI	0.027
ERW	0.025	THAI	0.024	TOC	0.024	BKI	0.025	TRUE	0.025
TRUE	0.025	THRE	0.023	DTC	0.023	MFC	0.024	MTI	0.025
CSC	0.024	TOC	0.022	MC	0.023	BAY	0.024	BH	0.024

Ranking of standardized average degree (network of directors)**

Std. Avg. Degree		Std. Avg. Degree		Std. Avg. Degree		Std. Avg. Degree		Std. Avg. Degree	
2012		2013		2014		2015		2016	
Mr. SUCHIN WANGLEE	0.042	Mr. SUCHIN WANGLEE	0.051	Mr. SUCHIN WANGLEE	0.054	Mr. SUCHIN WANGLEE	0.050	Mr. ARSA SARASIN	0.054
Mr. BOONSITHI CHOKWATANA	0.035	Mr. PRASERT BUNSUMPUN	0.049	Mr. PRASERT BUNSUMPUN	0.048	Mr. PRASERT BUNSUMPUN	0.046	Mr. SUCHIN WANGLEE	0.051
Mr. WEERAWONG CHITTMITRAPAP	0.034	Miss POTJANEE THANAVARANIT	0.044	Mr. MANU LEOPAIROTE	0.043	Mr. ARSA SARASIN	0.042	Mr. PRASERT BUNSUMPUN	0.051
Mr. APIPORN PASAWAT	0.034	Mr. MANU LEOPAIROTE	0.042	Mr. CHATCHAVAL JIARAVANON	0.042	Mr. MANU LEOPAIROTE	0.040	Mr. RAWAT CHAMCHALERM	0.046
Mr. BOONCHAI CHOKWATANA	0.033	Mr. BOONCHAI CHOKWATANA	0.041	Miss POTJANEE THANAVARANIT	0.040	Mr. WEERAWONG CHITTMITRAPAP	0.038	Mr. MANU LEOPAIROTE	0.044
Mr. CHACKCHAI PANICHAPAT	0.033	Mr. CHATCHAVAL JIARAVANON	0.038	Mr. ARSA SARASIN	0.038	Miss POTJANEE THANAVARANIT	0.037	Mr. SITHICHAI CHAIKRIANGKRAI	0.042
Mr. PRAJYA PHINYAWAT	0.033	Mr. BOONSITHI CHOKWATANA	0.038	Mr. BOONSITHI CHOKWATANA	0.038	Mr. CHATCHAVAL JIARAVANON	0.036	Mr. WEERAWONG CHITTMITRAPAP	0.038
Mr. CHATCHAVAL JIARAVANON	0.032	Mr. ARSA SARASIN	0.037	Mr. AVIRUTH WONGBUDDHAPITAK	0.037	Mr. CHOKCHAI AKSARANAN	0.036	Mr. THAPANA SIRIVADHANABHAKDI	0.038
Mr. MANU LEOPAIROTE	0.031	Mr. AVIRUTH WONGBUDDHAPITAK	0.037	Mrs. KULPATRA SIRODOM	0.037	Mrs. KULPATRA SIRODOM	0.035	Mr. BOONSITHI CHOKWATANA	0.036
Mr. WISSANU KREA - NGAM	0.031	Mr. PRAJYA PHINYAWAT	0.037	Mr. JOTI BHOKAVANIJ	0.037	Mr. BOONSITHI CHOKWATANA	0.034	Mr. CHATCHAVAL JIARAVANON	0.035

** This is an outcome of scientific computation. With all best regards, the author has no intention of creating any negative consequences to all directors listed in this table.

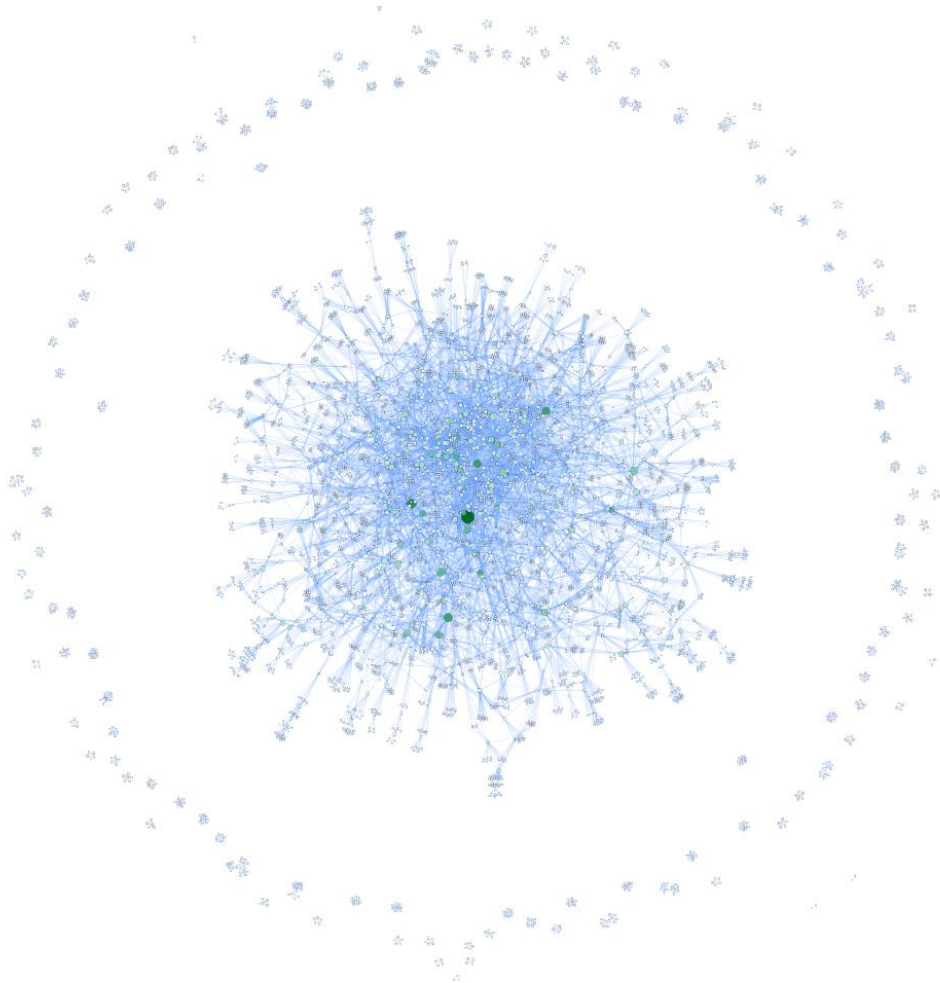
Ranking of standardized average degree (network of boards of listed companies)

Std. Avg. Degree		Std. Avg. Degree		Std. Avg. Degree		Std. Avg. Degree		Std. Avg. Degree	
2012		2013		2014		2015		2016	
SSC	0.043	ERW	0.044	ERW	0.044	THRE	0.043	SSC	0.049
ERW	0.042	SSC	0.044	THRE	0.042	ERW	0.041	SCC	0.037
HIPRO	0.040	HIPRO	0.042	HIPRO	0.041	HIPRO	0.040	TRUE	0.037
TRUE	0.037	THRE	0.041	SSC	0.041	TRUE	0.040	DTC	0.036
SPI	0.035	TRUE	0.041	TRUE	0.041	SCC	0.038	HIPRO	0.036
SCC	0.034	MINOR	0.036	SCB	0.038	SSC	0.038	TOC	0.036
MINOR	0.032	SCB	0.036	MINOR	0.036	DTC	0.037	ERW	0.034
MPT	0.032	LOXLEY	0.035	SCC	0.035	SCB	0.037	MINOR	0.033
TOC	0.031	TOC	0.035	DRT	0.032	TOC	0.037	LOXLEY	0.031
DRT	0.029	DRT	0.032	MPT	0.032	MINOR	0.035	SPI	0.028

2.2 Malaysia's Stock Market

2.2 Malaysia's Stock Market

Network of directors (all listed companies)



Source: Authors' calculation

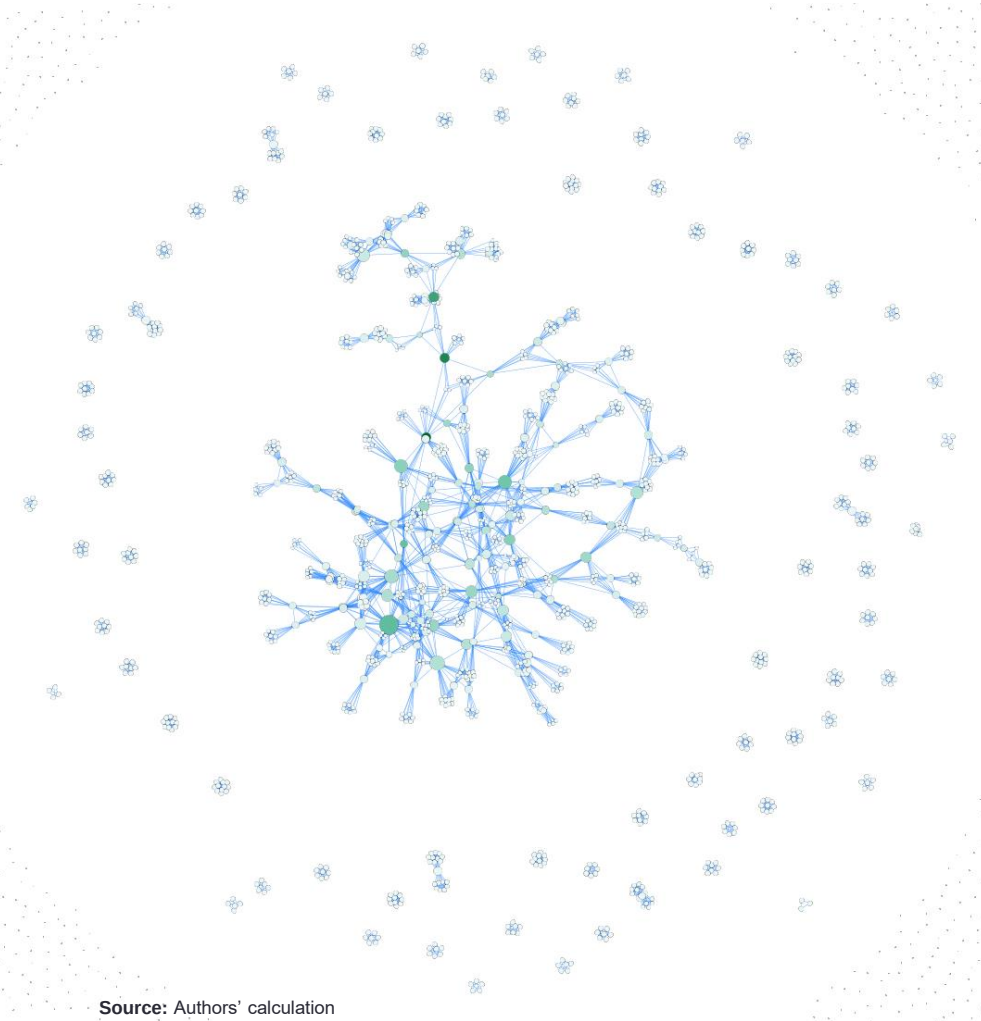
Network of boards of firms (all listed companies)



Source: Authors' calculation

2.2 Malaysia's Stock Market

Network of directors (Shariah companies)



Source: Authors' calculation

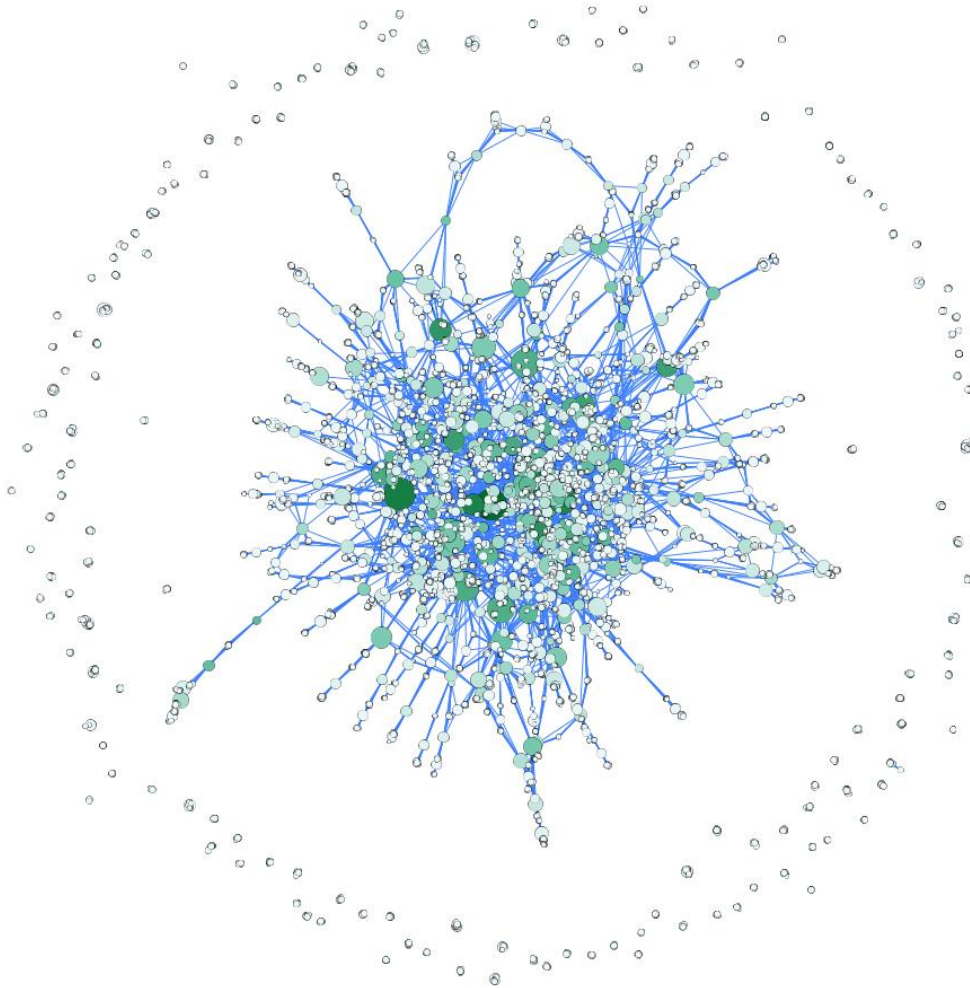
Network of boards of firms (Shariah companies)



Source: Authors' calculation

2.2 Malaysia's Stock Market

Network of directors (non-Shariah companies)



Source: Authors' calculation

Network of firms (non-Shariah companies)



Source: Authors' calculation

2.2 Malaysia's Stock Market

Summary of key indicators of network's properties (the network of directors)

Year	Density	Standardized average degree	Closeness index	Eigen index	Diameter	Transitivity index	Average shortest path length
All companies	0.001409	0.014104	0.000268	0.992079	15	0.894486	5.841254
Shariah companies	0.000335	0.008596	4.33E-05	0.99594	15	0.948288	6.138625
Non-Shariah companies	0.001102	0.007673	0.000212	0.996407	15	0.910153	6.365366

Source: Authors' calculation

The values of average shortest path length of all three cases are very close to **6.0**, which confirm the characteristics of **Six Degrees of Separation** in financial market. This validates the **structure of human society** in connections among boards of directors.

2.2 Malaysia's Stock Market

Summary of key indicators of network's properties (the network of listed companies)

Year	Density	Standardized average degree	Closeness index	Eigen index	Diameter	Transitivity index	Average shortest path length
All companies	0.004578	0.021429	0.001493	0.972785	20	0.43758	4.93844
Shariah companies	0.009746	0.05086	0.005948	0.953985	18	0.296779	5.390903
Non-Shariah companies	0.004194	0.01494	0.001663	0.970057	21	0.463025	5.473917

Source: Authors' calculation

The values of average shortest path length of all three cases **are lower than 6.0**, showing the **shorter path connecting listed companies** through interlocking board members.

Most significant persons in the network of boards of directors (all companies)

Weighted Degree		Betweenness Index		PageRank Index	
Ooi Teik Huat	120	Ooi Teik Huat	0.0382	Ooi Teik Huat	0.0382
Megat Abdul Rahman Bin Megat Ahmad	82	Megat Abdul Rahman Bin Megat Ahmad	0.0305	Megat Abdul Rahman Bin Megat Ahmad	0.0305
Abdul Azim Bin Mohd Zabidi	82	Lim Hun Soon @ David Lim	0.0271	Lim Hun Soon @ David Lim	0.0271
Koh Kin Lip	78	Oh Chong Peng	0.0266	Oh Chong Peng	0.0266
Norraesah Binti Mohamad	76	Abdul Azim Bin Mohd Zabidi	0.0265	Abdul Azim Bin Mohd Zabidi	0.0265
Lim Hun Soon @ David Lim	72	Zainun Aisyah Binti Ahmad	0.0239	Zainun Aisyah Binti Ahmad	0.0239
Oh Chong Peng	63	Megat Najmuddin Bin Megat Khas	0.0239	Megat Najmuddin Bin Megat Khas	0.0239
Tengku Sulaiman Shah Al-Haj Ibni Almarhum Sultan Salahuddin Abdul Aziz Shah Al-Haj	60	Teh Kean Ming	0.0227	Teh Kean Ming	0.0227
Esther Tan Choon Hwa	60	Fateh Iskandar Bin Mohamed Mansor	0.0219	Fateh Iskandar Bin Mohamed Mansor	0.0219
Ahmad Bin Mohd Don	59	Ali Bin Abdul Kadir	0.0217	Ali Bin Abdul Kadir	0.0217

Source: Authors' calculation

Most significant firms in the network of all listed companies

Weighted Degree		Betweenness Index		PageRank Index	
RANHILL UTILITIES BHD	58	IJM LAND BERHAD	0.0414	IJM LAND BERHAD	0.0031
RANHILL BERHAD	58	SARAWAK OIL PALMS BERHAD	0.0272	SARAWAK OIL PALMS BERHAD	0.0030
RANHILL POWER BERHAD	58	MALAKOFF CORPORATION BERHAD	0.0243	MALAKOFF CORPORATION BERHAD	0.0030
RANHILL HOLDINGS BERHAD	53	MALAYSIAN AIRLINE SYSTEM BERHAD	0.0232	SUNWAY BERHAD	0.0027
YTL CORPORATION BERHAD	42	GLOMAC BERHAD	0.0223	MALAYSIAN AIRLINE SYSTEM BERHAD	0.0027
SIME DARBY BERHAD	41	OMESTI BERHAD	0.0219	RANHILL UTILITIES BHD	0.0026
BOUSTEAD PLANTATIONS BERHAD	41	MALAYSIAN RESOURCES CORPORATION BERHAD	0.0214	RANHILL BERHAD	0.0026
MALAKOFF CORPORATION BERHAD	38	TELEKOM MALAYSIA BERHAD	0.0211	RANHILL POWER BERHAD	0.0026
YTL CEMENT BERHAD	38	M3ENERGY BERHAD	0.0191	PERUSAHAAN OTOMOBIL NASIONAL BHD	0.0026
BOUSTEAD HOLDINGS BHD	38	SUNWAY BERHAD	0.0187	PROTON HOLDINGS BERHAD	0.0026

Source: Authors' calculation

Most significant persons in the network of boards of directors (Shariah companies)

Weighted Degree	
Ooi Teik Huat	64
Nik Norzrul Thani Bin Nik Hassan	41
Azmi Bin Mohd Ali	41
Johan Bin Abdullah	39
Jorgen Bornhoft	38
Jamaludin Bin Osman	34
Gee Siew Yoong	32
Tunku Afwida Binti Tunku A.Malek	32
Lee Chun Fai	31
Che Khalib Bin Mohamad Noh	30

Betweenness Index	
Ooi Kim Lai	0.0059
William Cheng	0.0050
Mohamad Kamarudin Bin Hassan	0.0040
Ooi Teik Huat	0.0031
Kamal Bahrin Bin Ahmad	0.0030
Azmi Bin Mohd Ali	0.0027
Noraini Binti Che Dan	0.0022
Ab Halim Bin Mohyiddin	0.0021
Mohd Bakke Bin Salleh	0.0020
Tunku Alina Binti Raja Muhd Alias	0.0020

PageRank Index	
Ooi Teik Huat	0.0018
Johan Bin Abdullah	0.0014
Nik Norzrul Thani Bin Nik Hassan	0.0013
Azmi Bin Mohd Ali	0.0013
Ab Halim Bin Mohyiddin	0.0012
Lee Chun Fai	0.0012
Azzat Bin Kamaludin	0.0011
Gee Siew Yoong	0.0011
Tunku Afwida Binti Tunku A.Malek	0.0011
Jorgen Bornhoft	0.0011

Source: Authors' calculation

Most significant firms in the network of Shariah companies

Weighted Degree	
MALAKOFF CORPORATION BERHAD	17
SARAWAK OIL PALMS BERHAD	16
MMC CORPORATION BERHAD	11
SIME DARBY BERHAD	10
GAS MALAYSIA BERHAD	10
DRB-HICOM BERHAD	9
IJM CORPORATION BERHAD	9
SUNWAY BERHAD	9
SP SETIA BHD	8
AEON CO. (M) BERHAD	8

Betweenness Index	
PARKSON HOLDINGS BERHAD	0.1226
LION DIVERSIFIED HOLDINGS BERHAD	0.0955
PETRONAS GAS BHD	0.0879
SIME DARBY BERHAD	0.0774
MALAYSIAN PACIFIC INDUSTRIES BHD	0.0678
MALAKOFF CORPORATION BERHAD	0.0589
GAS MALAYSIA BERHAD	0.0570
SP SETIA BHD	0.0532
TENAGA NASIONAL BERHAD	0.0466
SARAWAK OIL PALMS BERHAD	0.0424

PageRank Index	
SUNWAY BERHAD	0.0191
MALAKOFF CORPORATION BERHAD	0.0188
SARAWAK OIL PALMS BERHAD	0.0179
SIME DARBY BERHAD	0.0163
MALAYSIAN PACIFIC INDUSTRIES BHD	0.0152
TENAGA NASIONAL BERHAD	0.0148
SP SETIA BHD	0.0143
RANHILL HOLDINGS BERHAD	0.0130
IJM CORPORATION BERHAD	0.0122
LION DIVERSIFIED HOLDINGS BERHAD	0.0122

Source: Authors' calculation

Most significant persons in the network of boards of directors (non-Shariah companies)

Weighted Degree		Betweenness Index		PageRank Index	
Ghazali Bin Mohd Ali	72	Ghazali Bin Mohd Ali	0.0345	Pan Ding	0.0009
Nik Norzrul Thani Bin Nik Hassan	69	Pan Ding	0.0287	Ghazali Bin Mohd Ali	0.0009
Amiruddin bin Abdul Satar	66	Ahlan Nasri Bin Mohd Nasir	0.0283	Siti Fatimah binti Daud	0.0008
Pan Ding	60	Mustapha Bin Buang	0.0274	Wong Thean Soon	0.0008
Abu Hassan Bin Othman	59	Nik Norzrul Thani Bin Nik Hassan	0.0262	Nik Norzrul Thani Bin Nik Hassan	0.0008
Syed Abdullah Bin Syed Abd Kadir	58	Liao Yuan Shun	0.0230	Lee Yoke Har	0.0008
Siti Fatimah binti Daud	56	Hiroaki Yano	0.0218	Ahlan Nasri Bin Mohd Nasir	0.0007
Yasmin Binti Aladad Khan	51	Chan Bee Leng	0.0190	Simon Shim Kong Yip	0.0007
Yeoh Soo Min	51	Edward Chong Sin Kiat	0.0184	Sharifuddin Bin Shoib	0.0007
Eu Peng Meng @ Leslie Eu	51	Kamariyah Binti Hamdan	0.0182	Lim Sin Khong	0.0007

Source: Authors' calculation

Most significant firms in the network of non-Shariah companies

Weighted degree		Betweenness Index		PageRank Index	
GROMUTUAL BERHAD	42	GLOBAL ORIENTAL BERHAD	0.0487	MALAYAN FLOUR MILLS BHD	0.0034
N2N CONNECT BERHAD	39	MALAYAN FLOUR MILLS BHD	0.0356	GLOBAL ORIENTAL BERHAD	0.0034
MPHB CAPITAL BERHAD	39	JOHOR LAND BERHAD	0.0308	CYGAL BERHAD	0.0031
MOL ACCESSPORTAL BERHAD	39	CYGAL BERHAD	0.0291	PUC FOUNDER (MSC) BERHAD	0.0031
HAP SENG PLANTATIONS HOLDINGS BERHAD	38	Y&G CORPORATION BERHAD	0.0280	BP PLASTICS HOLDING BHD	0.0029
INNOPRISE PLANTATIONS BERHAD	29	HIGHLANDS & LOWLANDS BERHAD	0.0280	KHIND HOLDINGS BERHAD	0.0029
SHANGRI-LA HOTELS (MALAYSIA) BHD	28	BTM RESOURCES BHD	0.0278	BLD PLANTATIONS BERHAD	0.0029
HONG LEONG BANK BERHAD	27	PUC FOUNDER (MSC) BERHAD	0.0265	N2N CONNECT BERHAD	0.0029
C.I. HOLDINGS BERHAD	26	RAYA INTERNATIONAL BERHAD	0.0247	MPHB CAPITAL BERHAD	0.0029
TECHNODEX BERHAD	26	FAR EAST ASSETS BHD	0.0227	MOL ACCESSPORTAL BERHAD	0.0029

Source: Authors' calculation

3. Application on Macroeconomics

3.1 International Trade

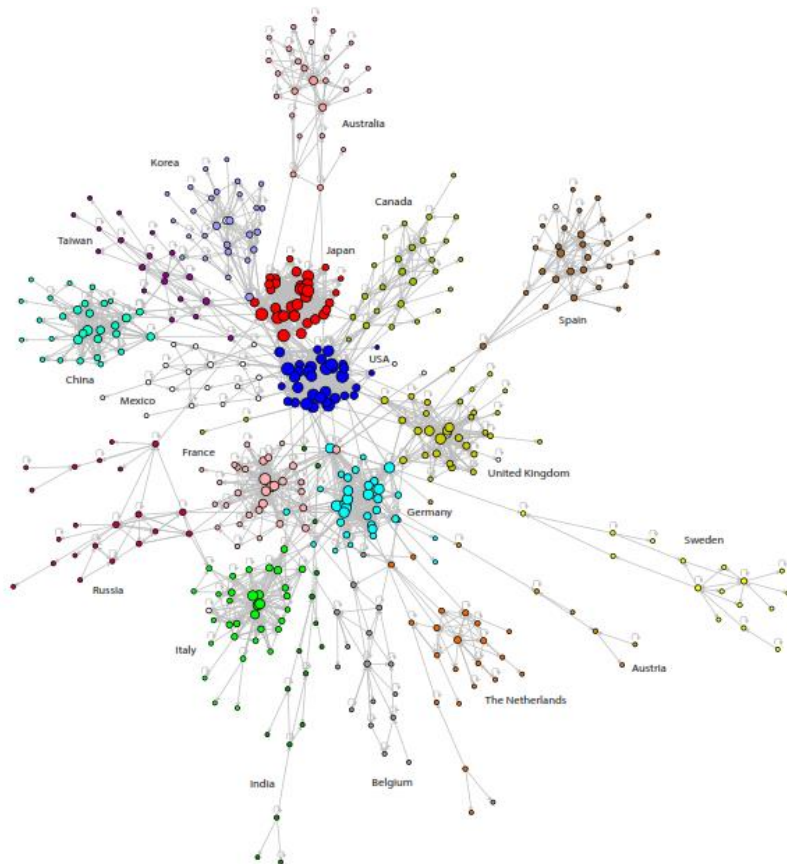
3.2 US Economy

3.3 Thai Economy

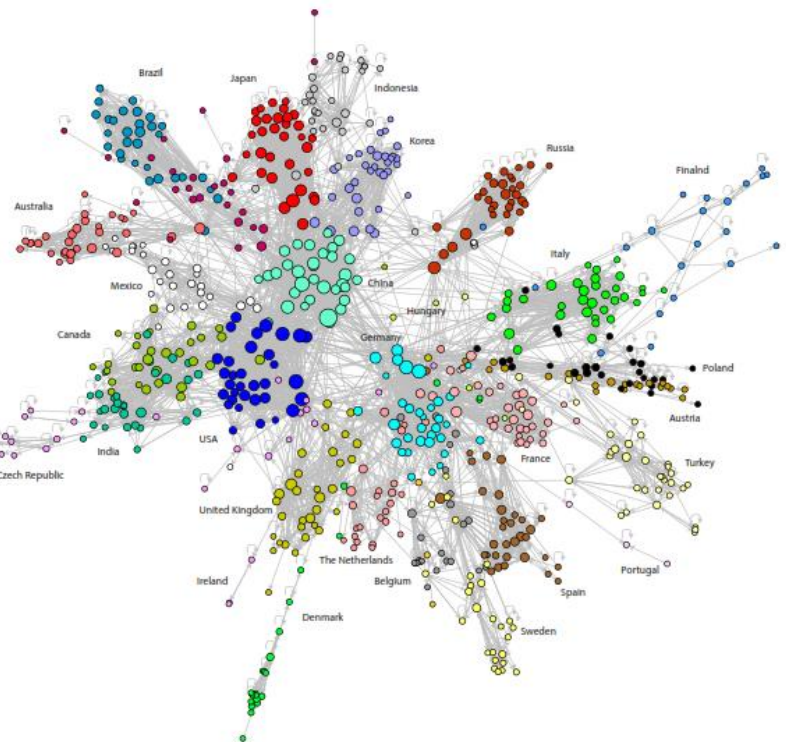
3.1 International Trade

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80																				

Result of Applying the Network Analysis to Global IO Tables



(a)1995



(b)2011

Source: Cerina et al.(2014)

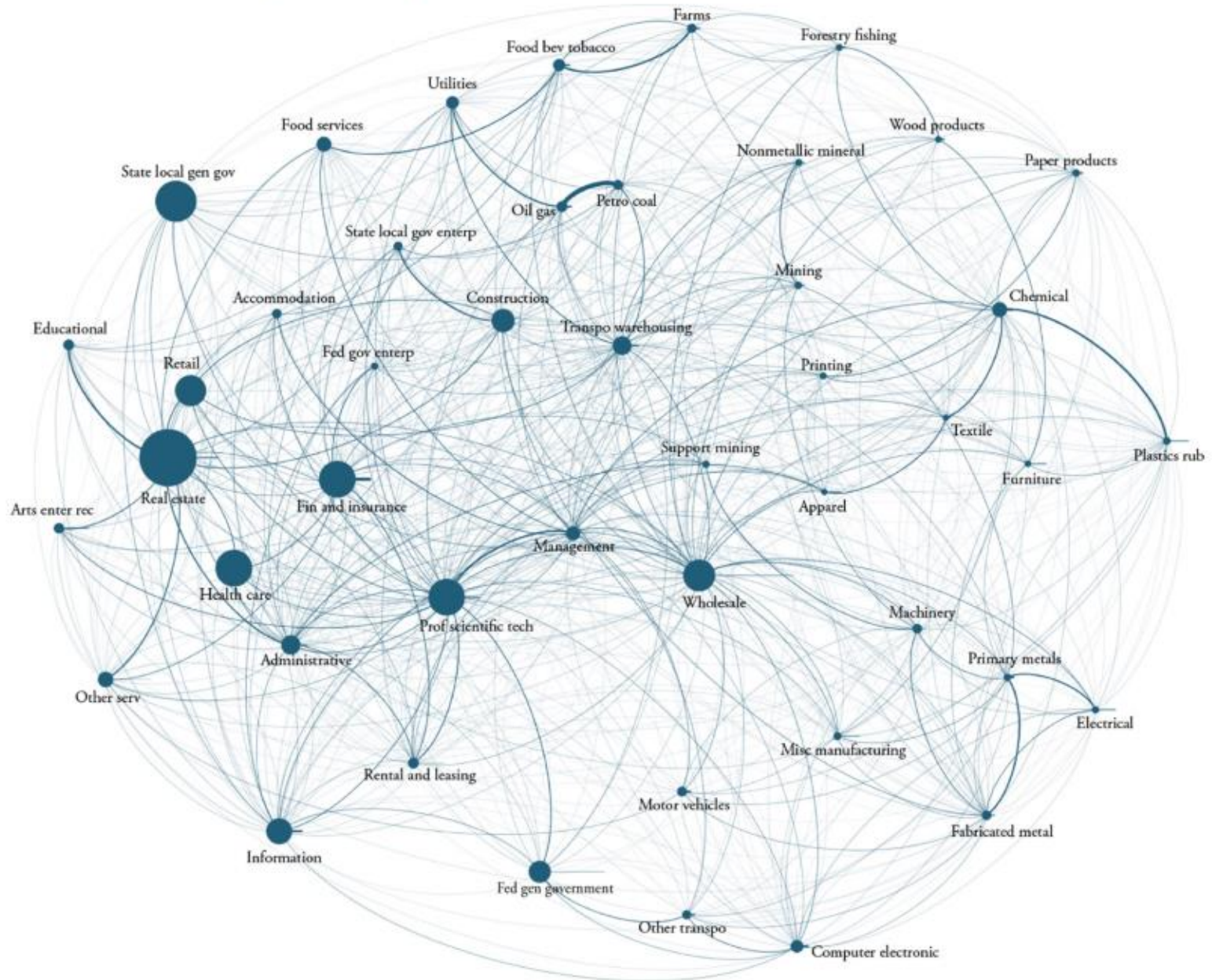
3.2 US Economy

The U.S. Input-Output Network in 1947



Sources: Bureau of Economic Analysis and authors' calculations.

The U.S. Input-Output Network in 2015



Sources: Bureau of Economic Analysis and authors' calculations.

3.3 Thai Economy

Network Analysis of Thai Economy

(Based on Social Accounting Matrix 2015)

