CHAPTER 1

Case Study: International Trading Networks

In previous chapters, we introduced the hybrid visualization approach which determines the layout of a multivariate network according to the vertices' attributes and relationship. A user study was conducted to verify the effectiveness of this method. In this chapter, we will demonstrate the capability of the hybrid approach by visualizing two sets of world trade networks. The first set of networks describe the trading of manufactured metal and cereal between 80 countries in 1994. The second set of networks represent the international weapon transferring activities from 1983 to 1999.

The chapter is organized as follows. Section 1.1 introduces theories established by the economic researchers about the world trading networks. In Section 1.2 and Section 1.3, we apply the hybrid approach to visualize the trading of cereals, metals and weapons between countries. The discussion is focus on how the visualization can help viewers understand the economic theories and discover the trading patterns. Conclusions are presented in Section 1.4.

1.1 Introduction to International Trading Networks

International trade can be considered as the backbone of modern commercial world. Companies in various nations try to make bigger profits from the global market, rather than being limited to trade within their own borders. Trading between countries are affected by many factors such as the countries' economic powers, political relationships and technology status etc. By analyzing the world trade network, economic researchers aim to reveal the structure of the world economic systems, the roles that countries play within the international division of labor and how these two aspects change with time. It is believed that these three factors are crucial to understand "a wide array of social, political and economic changes with in particular societies" [17]. In addition, researchers try to explain the existence of trade or predict the trading levels between different countries based on the countries' characteristics.

1.1.1 World-System Theory

The well-known world-system theory [18] divides the countries into a hierarchy of core, semi-periphery and periphery. The core represents the advanced and industrialized countries which focus on capital-intensive production. Periphery, on the other hand, refers to weak and poor countries whose production process is labor-intensive. Semi-periphery countries act as buffer zone between the core and the periphery. They have achieve a certain degree of manufacturing but mainly export minerals/agricultural goods. In other words, the semi-periphery countries are still in the process of economic development and lack the economic dominance of core nations.

In fact, the world-systems theory argues that a country's position in the world entomic system determines what types of commodities are exchanged and with whom [19, 20]. It is expected that most of the high level economic activities and innovations are located at the core. The periphery countries supply raw materials, agricultural products and cheap labor to the core countries and depend on the core countries for complex products. The core countries trade heavily with each other while the periphery countries's overall level of exchanges is very small and center in the core [16]. The world system theory also claims that there exist unequal exchanges (asymmetry in trade flows) between core and semi-periphery/periphery.

Economic researchers classify the countries into core, semi-periphery/periphery by mathematically analyzing the countries' structural equivalence in the international trading networks [15, 11, 14, 7]. Countries with structural equivalence means they have similar trading volumes in all types of commodities sectors(e.g. high technology heavy manufacture, simple extractive, food products etc.). Table 1.1 shows the classification results by Mahutga [7] at year 1990. The classification was based on the international trading of 55 commodities. In the table, semi-periphery were further split into two sub-categories: strong semi-periphery and weak semi-periphery.

1.1.2 Correlation of The Countries' Attributes and Trade

Besides understanding the world economic structure, researchers especially the neoclassical economic theorists are interested in establishing mathematical models to explain/predict the trading levels between countries [4, 9, 6, 10]. The mathematical models incorporate various attributes of the countries which have most significant impact on the trading levels. Significance of the attributes are found by calculating the correlation between the value of the attribute and the actual amount of trade. For example, Gaile and Grant [9] mathematically evaluate the impact of several attributes

Table 1.1: Classification of the countries into core (1), strong semi-periphery (2), weak-semi-periphery (3), periphery (4) in year 1990 [7].

Country	Strata	Country	Strata	Country	Strata
United States	1	Singapore	2	Philippines	3
Germany	1	Spain	2	Israel	3
Great Britain	1	South Korea	2	Morocco	3
France	1	Ireland	2	Guatemala	3
Italy	1	Thailand	2	Hungary	3
Netherlands	1	Mexico	2	Peru	3
Japan	1	Portugal	2	Pakistan	3
Sweden	2	Brazil	2	Bolivia	4
Canada	2	Malaysia	2	Jordan	4
Switzerland	2	Chile	3	Turkey	4
Denmark	2	Venezuela	3	Iceland	4
Belgium	2	El Salvador	3	Togo	4
Greece	2	Costa Rica	3	Ecuador	4
Australia	2	Paraguay	3	Senegal	4
Finland	2	Columbia	3	Nicaragua	4
Austria	2	Honduras	3		
Norway	2	Malta	3		
Hong Kong	2	Tunisia	3		
New Zealand	2	Argentina	3		

to the countries' bilateral trading levels. They found that the Gross National Product (GNP), second/tertiary education level, military expenditure have the highest positive correlation with the trading. On the other hand, attributes such as the country size, population and population growth have low correlation with the trading values. Distance between the countries actually have negative effect on the trading values, which means the further apart of two countries, the less amount of trade between them. Other studies [10, 13] showed that common languages, price level and exchange rates, share borders all account for significant variance of the trading level.

From the above discussion, we can see that the international trading networks are typically multivariate networks. Trading of different goods form various relationships between the countries. In addition, each country has multiple attributes such as population, GNP, education level, population etc. Both of the countries's attributes and trade flows are important to understand the world economic system.

Economic researchers study the international trading networks based on complex mathematical models. The results are usually listed in lengthy tables such as Table 1.1. In the follows sections, we are going to demonstrate how the hybrid visualization approach can help viewers understand the world trade networks. We do not mean that the visualization are better than the rigorous math-

ematical analysis. On the contrary, it serves as a tool to help viewers build their mental maps of the complex international trading network and better understand the analysis results. Due to data availability, we are only able to collect two sets of world trade networks. The first data set describes the trading of cereals and manufacture metal between the same set of countries. The second set of network are the world arms transfer activities in two periods: 1983-1991 and 1992-1999.

1.2 Cereals and Manufactured Metal Tradings

These two networks were extracted from the Pajek database [5]. They describe the cereals and manufactured metal trading between 80 countries in 1994. Each country has four attributes: Gross Domestic Product (GDP) per capita, GDP Growth, population and population growth. The cereal trading network has 230 edges and the manufactured metal network has 248 edges. The edge are directed, pointing form exporting countries to exporting countries. Some edges are double directed because both countries export the same types of commodity to each other. Each edge is associated with the corresponding trading value in US dollars.

Table 1.2 shows the two networks's diameters (D), mean pairwise distance μ, distance variance σ, skewness s and the best values of constant ξ in equation **??**. Attributes of the countries have very different scale. For instance, the population growth have a range of [0,1], but the population varies from several thousand to a billion. Hence, before the training, the attributes are all normalized to the range of $[0, 1]$. For both networks, the GeoSOM used a three frequency geodesic dome as the grid which contains 92 neurons. It was trained for 600 epochs. Training of the cereals network took 7.1 seconds and the spherical disk layout took 19.2 seconds. Training of the manufacture metal network took 9.0 seconds and the spherical disk layout took 22.5 seconds.

Table 1.2: Statistics of the cereals trading network and manufactured metal trading network.

	D	μ	σ	s	ξ
Cereal Trading Network	5	2.36	0.75	0.54	0.5
Metal Trading Network	3	1.98	0.48	-0.05	-0.05

Hybrid visualizations of the two international trading networks are shown in Figure 1.2. For space reasons, country names are displayed in their standard three letters abbreviation form [3]. The trading values are mapped to different transparency levels of the edges. The higher the value, the darker of the edges. Furthermore, in order to show the balance of trade, two ends of each edge are of different widths(see Figure 1.1). The widths are proportional to the corresponding countries'

exporting value.

(a) A exports more goods to B. (b) The trade is balanced (c) B exports more goods to A.

Figure 1.1: Width of the edges' end points indicate the balance of trade between two countries.

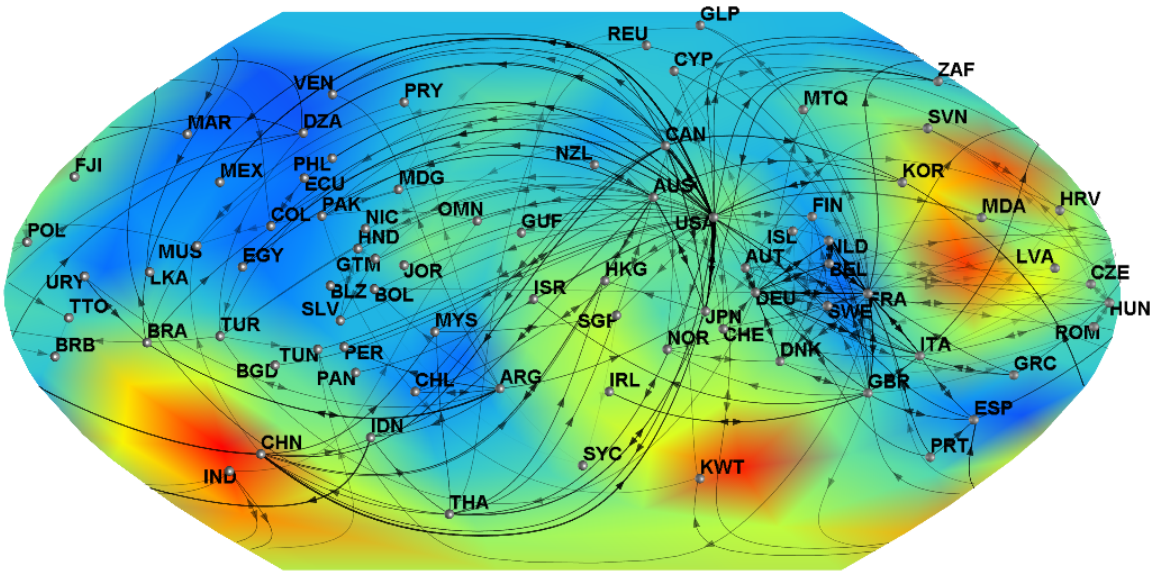
1.2.1 The Trading Patterns

We first discuss the countries' trading patterns. In Figure 1.2(a) and Figure 1.2(b), countries belong to the core (e.g. United States (USA), Japan (Jap), Germany (DEU)) are located in the middle right region. The semi-periphery/periphery countries such as South Korea (KOR), Tunisia (TUN) and Peru (PER) are scattering around the core countries (please refer to Table 1.1):

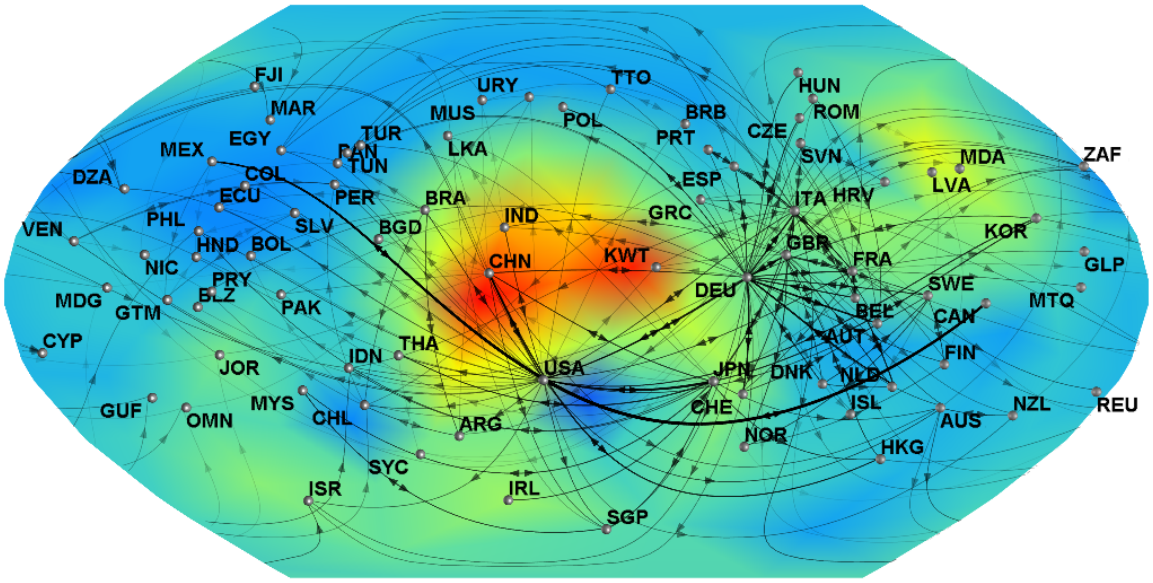
1. In visualizations of the cereal trading network (see Figure 1.2(a)), most edges of the the periphery countries are single directed pointing from the core countries. This indicates the periphery countries were depending on the core countries for cereals. The USA was the world's biggest cereal supplier who exported cereals to seventy nations in 1994. Other key exporters include Canada (CAN), Australia (AUS), Germany (DEU) and China (CHN). Japan (JAP) was the world's NO.1 cereal importer who mainly bought cereals from USA and China.

2. Similar trading patterns can be observed from the manufactured metal trading network (see Figure 1.2(b)): The periphery countries highly depended on the core countries for manufactured metal products. The USA remained the biggest exporter. Germany, Great Britain (GBR) and Italy replace Canada, Australia and China as the major suppliers. From the edge widths, the highest value of trade are made between the USA and Canada, the USA and Mexico. The arrows and edge widths showed the trading are balanced. Compared to the cereal trading network, the balance of trade between Japan and the USA was reversed. The USA imported more manufactured metal from Japan (198 million dollars) than exported to Japan (68 million dollars).

3. In both networks, trading within the core or the strong semi-periphery are much denser than within the periphery countries. In addition, most of the edges between the core or strong semi-periphery are double directed and the two end points of the edges are of the same width.



(a) The cereals trading network



(b) The manufactured metal trading network

Figure 1.2: Visualizations of the two world trade networks.

These observations suggest the trading among the core or strong semi-periphery are balanced. They do not depend on each other for the product supply.

Most of the above observations are consistent with the world-system theory: core countries such as the USA, Germany and Japan were key providers of high-processed commodities (manufactured metal). Strong Semi-periphery countries (e.g. Australia and Canada) mainly exported agricultural goods. The weak semi-periphery/periphery countries (e.g. Honduras (HND),Ecuador (ECU)) re-

lied on the core and strong semi-periphery for product supplies. However, according to the world system theory, the core countries should be specialized in exporting complex manufacturing products and the periphery countries tend to supply agricultural products. Figure 1.2(a) demonstrates that core countries are also the major provider of cereals to the periphery countries. This probably because the massive production of some agriculture goods rely more and more on high technology, especially the techniques for genetically modified foods, manufacturing agricultural machinery and equipments. Therefore, the advanced core countries are able to produce more cereals at much lower prices.

1.2.2 The Attribute Distribution

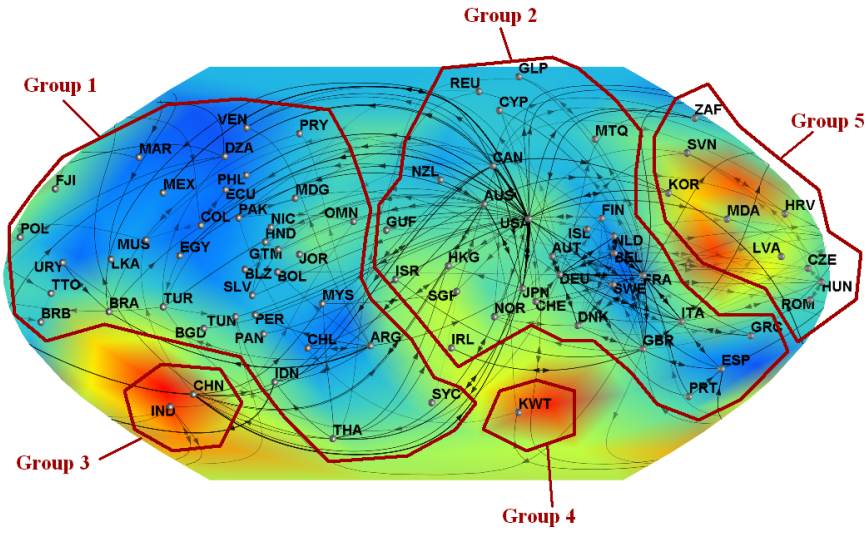
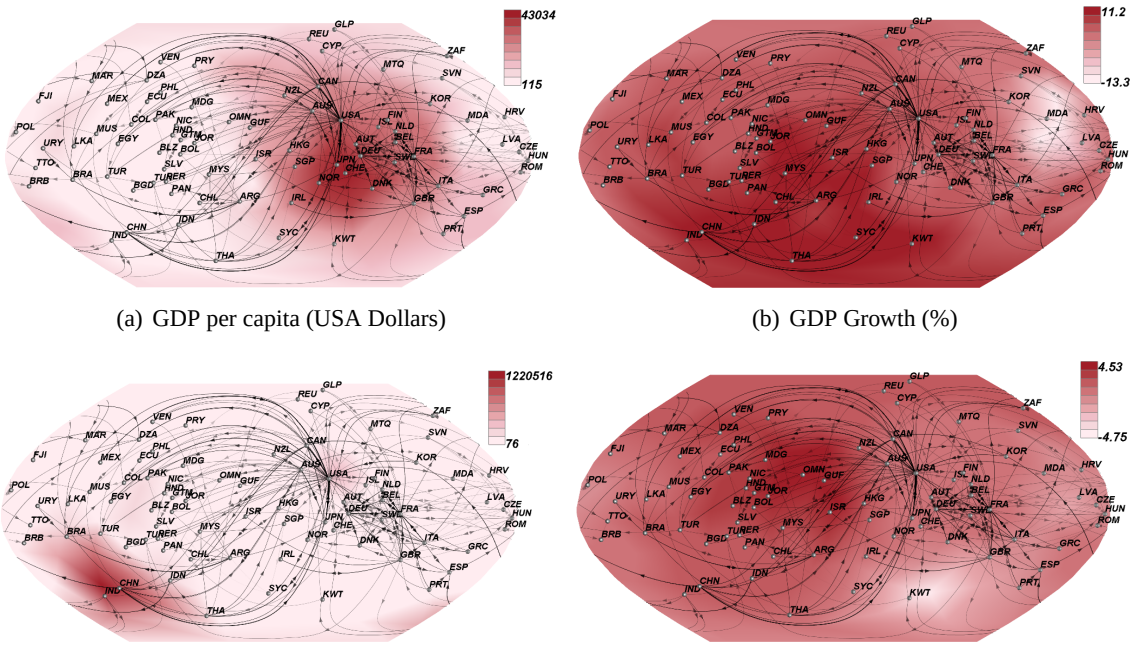


Figure 1.3: The countries can be roughly classified into five groups according to their attributes.

Because vertices (countries) in both networks are the same, discussion of the attribute distributions will be based on only one of the networks — the cereal trading network. Several clusters of countries can be observed from the visualization as shown in Figure 1.3. There are two continuous blue regions. Countries such as Sri Lanka (LKA), Pakistan (PAK), Honduras (HND) are located on the upper-left blue region. In the following discussion, we will refer to this group as Group 1. Countries such as the USA, Great Britain and Germany are mapped to the central-right blue region, we will refer to these countries as Group 2. There are three small groups of countries located in separate bright color regions. As introduced at Section **??**, neurons in bright color regions have very different weight vectors. Therefore, countries mapped to these neurons have distinguished attribute values:

- China and India (IND). (Group 3)
- Kuwait (KWT). (Group 4)
- Moldavia (MDA), South Korea (KOR), Latvia (LVA), Croatia (HRV), Slovenia (SVN), Czech Republic (CZE). (Group 5)

Figure 1.2 shows the structure of the countries' attribute space. Viewers may also want to know what attributes makes the countries different from each other. What is the biggest or lowest value of an particular attribute. These questions can be solved using the component planes. As introduced at Section **??**, in a component plane, colors of the neurons represent the changes of a selected attribute so that we can visualize the distribution of that attribute across the network. We generate an interface which allows a viewer to see the component plane of selected attributes. Figure 1.4 shows the four component planes of the cereal world trade network.



(a) GDP per capita (USA Dollars)

(b) GDP Growth (%)

(c) Population (thousand)

(d) Population Growth (%)

Figure 1.4: Component planes of the cereal world trade network.

- Component plane of GDP per capita (see Figure 1.4(a)) illustrates that the countries located on the left of the visualization are the low income developing countries. Most of them belong to Group 1. Their average individual income in 1994 was less than three thousand dollars. The poorest country was Madagascar (MDG) whose GDP per capita was only $115. Countries located in the central-right blue region (Group 2) are the wealthy developed countries.

The average GDP per capita of this group was around $20,000. Switzerland was the country with highest GDP per capita ($43034), followed by Japan ($40920), Norway ($33708).

- Figure 1.4(b) shows the distribution of GDP growth. In general, the low income countries had higher economic growth than the wealthy countries. China was the only country whose GDP growth was more than ten percent (11.2%). On the other hand, some countries experienced down turn in their economics and had negative GDP growth. For example, Moldavia (MDA)'s GDP growth is -13.3%, Latvia (LVA)'s GDP Growth was -8.3% and South Korea's GDP grow was -4.9%. Compared with Figure 1.3, we can see that these countries all belong to Group 5.

- The population distribution is shown in Figure 1.4(c). As we can see, countries in Group 3 (China and India) had the largest population in the world. They have 1220 million and 900 million people respectively.

- The last component plane (Figure 1.4(d)) shows the distribution of population growth. On average, the population increased faster in developing countries than in the developed countries. French Guiana had the highest population growth rate in the world (4.53%). On the other hand, all countries in Group 5 had negative or close to zero population growth. For example, the growth rate of Latvia was -1.13% and growth rate of Croatia is -0.11%. Country with the lowest population growth rate was Kuwait (-4.75%). This explains why Kuwait is mapped to a separate bright color region in the visualization. The decline in population was probably caused by the Persian Gulf war in early 1990s.

1.2.3 Correlation of Between Trading Activities and The Attributes

The previous two sections discussed the countries' trading patterns and attributes distributions separately. Here we are going to find the correlation between the trading activities and the countries attributes.

Figure 1.3 shows that the countries can be put in to five groups according to their attribute similarities. Countries in Group 2 are the wealthy developed countries as shown by the component plane of GDP per capita 1.4(a). They also correspond to the core and strong semi-periphery countries who trade heavily with each other. On the other hand, the trading between/within countries in other four groups are of much lower levels. These observations are consistent with the analysis result of Gaile and Grant [9], which states that the countries' economic strength is the most important factor to determine the countries' bilateral trading values.

Other component planes also confirm Gaile and Grant's statements: the GDP growth, the population and population growth have low correlations with the bilateral trading levels. For example, China and India have the largest population in the world. However, in both trading network, these two countries did not exchange commodities with each other. The trading between countries with high population growth or GDP growth are also sparse.

Due to the data's availability, we are not able to show whether the countries' locations, languages or education levels have any impact on the trading activities. However, it is very easy to incorporate these factors into the visualization once the data are collected, since the GeoSOM is able to handle any number of attributes.

1.3 Military Expenditures and Arms Transfer

In the former application, we used two world trade networks to demonstrate how the hybrid visualization approach can help viewers compare different relationships between the same set of entities. In this section, we are going to visualize the world military expenditure and arms transfer networks in different time periods.

Military expenditure measures the total annual cost of maintaining a defence establishment. Compare to the money directed to other social services (e.g. provide AIDS control, eliminate starvation), our world is over-focus on military developments (see Figure 1.3). In 2005, the total military expenditures reach 1 trillion USA dollars — an average of $162 per person. Only about two days global military spending is able to ensure every child to go to school. Only 10% of the spending is enough to provide basic human needs to everyone on earth [2]. On the other hand, the trading of weapons is seriously affected by the countries' political relationships and purchasing powers. Therefore studies of military expenditure and arms transfer network are of great political and economical values.

1.3.1 The Data Set

We collected data from two sources: the Stockholm International Peace Research Institute (SIPRI) and the USA Department of State. SIPRI maintains an Arms Transfer Database which records the international trading of major conventional weapons from 1950 to present. Each record lists the export/import country and the transferred volume. The USA Department of State generates a yearly report called the World Military Expenditures and Arms Transfers (WMEAT). The WMEAT con-

Figure 1.5: A picture taken at the United Nations headquarter at New York. The diagram showes the propotion of global military spending to other expenditures in year 2000.

tains lengthy tables listing various indicators which measures the countries' military expenditures. However, we are only able to collect reports from 1983 to 1999. From each report, we extract eight indicators:

1. Gross national product per capita (GNP per capita). As we introduced before, it indicates the economic strength of a country.

2. Military expenditures per member of the armed forces (ME/AF). This variable measures the level of armament and military effort per soldier.

3. Percentage of military expenditure to gross national product (ME/GNP). This indicator measures a country's military burden.

4. Percentage of defense cost to the central government expenditures (ME/CGE). This variable also measures a country's military burden. It complements the ME/GNP ratio, since the ratio of Central Government Expenditure (CGE) to GNP varies considerably between the countries.

5. Military expenditures per capita (ME per capita). It calculates the amount of money each citizen paid to maintain the country's armed forces. Therefore, it provides "a general measure of the cost of security/defence".

6. Armed forces per 1000 people. This variable assesses the relative size of a country's arm forces.

7. Percentage of military imports to non-military imports. It reflects the dependent level of a country to other weapon suppliers.

8. Percentage of military export to non-military exports. This indicator measures the importance of a country's arm industry to other industries.

All the above eight variables are relative indicators of a country's military expenditure level. The relative indicators are able to evaluate the level of attention each country focus on her miliary developments.

1.3.2 Preprocess and Training

In order to show the networks' changes over a period of time, the data are divided into two sub-periods 1983-1991 and 1992-1999 (before and after the cold war). The country attributes are averaged over the years in each period. Some countries in war such as Afghanistan and Somalia have a lot of data missing. They are omitted from the data set. Countries belong to the former Soviet Union such as Ukraine, Czech Republic and Slovak only have data after 1992. Therefore they are also omitted from this analysis. The final data set contains 97 countries. The arms transfer network of 1983-1991 contains 192 edges and the 1992-1999 network contains 185 edges. Table 1.3 lists the two networks's diameters (D), mean pairwise distance μ, distance variance σ, skewness s and the best values of constant ξ in equation **??**.

Table 1.3: Statistics of the arms transfer networks in two periods

	D	μ	σ	s	ξ
1983-1991 Network	4	2.14	0.64	0.80	0.85
1992-1999 Network	4	2.19	0.65	0.52	0.45

For both arms transfer networks, we used a four frequency GeoSOM (162 neurons). Before the training, all variables are normalized to the range of [0,1]. Each network was trained for 600 epoches. Training of the 1983-1991 network took 19.7 seconds and the spherical disk layout took

13.9 seconds. Training of the 1992-1999 Network took 21.1 seconds and the spherical disk layout took 10.3 seconds.

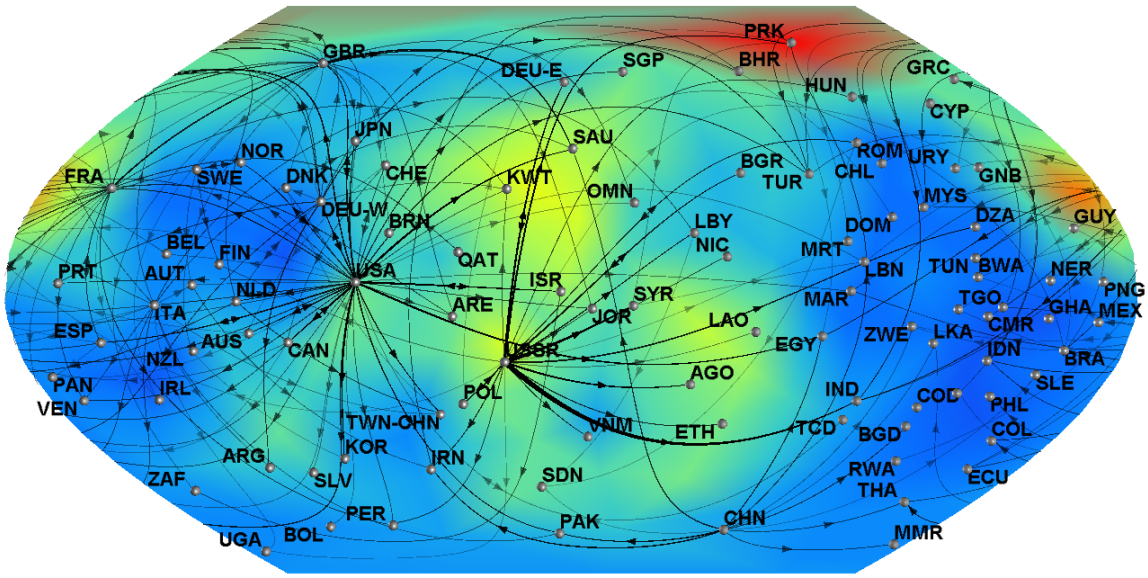
1.3.3 The Overviews

The final layouts of the two networks are shown in Figure 1.6(a) and Figure 1.6(b). Note that the attribute values in these two networks are different, they are the averages of 1983-1991 and 1992-1999 respectively. Several clusters can be observed from both two visualizations. Roughly speaking, countries on the left are those wealthy developed countries. On average, they spend more money on their armies than other countries. Countries mapped to the middle bright color regions direct large part of their resources (relative to their income) to military development. The remaining countries located on the right blue region are developing countries with low level of military expenditure. How the attributes' distributions change overtime will be discuss in detail using the component planes.

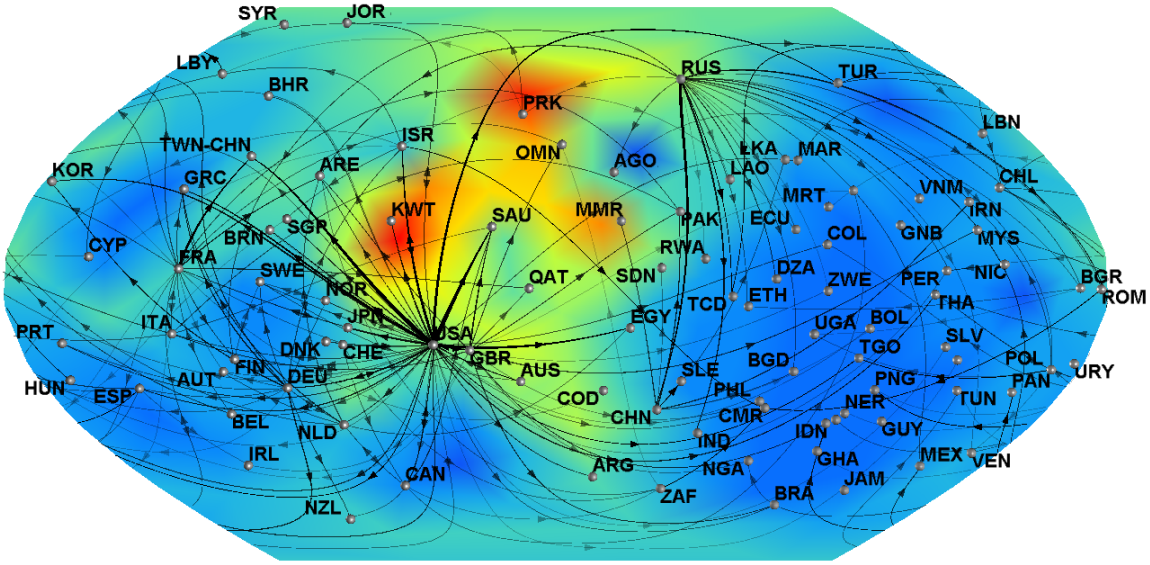
In the 1983-1991 network, the USA and the Soviet Union (USSR) were two dominant weapon providers during the period of 1983-1991. While most customers of the USA belonged to the developed countries, the USSR mainly exported weapons to developing countries such as India (IND), Bulgaria (BGR), Lebanon (LBN) and North Korea (PRK). Although the USA seems to have more customers, exporting volumes of the USSR are bigger than that of the USA. Other major weapon providers include France (FRA), Great Britain (GBR), Italy and China. Interestingly, the five permanent members of the United Nations' Security Council are all leading weapon suppliers. India and Saudi Arabia were the two biggest weapon importer during this period as shown by the width of their edges.

After the cold war (1992-1999), the Soviet Union became Russia Federation (RUS), who continued to be the dominant weapon suppliers of the developing countries. However, she had been surpassed by the USA in both the number of customers and the trading volumes. The main weapon recipients of Russia were India and China. Likewise, France, Great Britain, Italy and China's role as major weapon providers also shrank as indicated by their number of edges and edge widths. In the mean time, Taiwan (TWN-CHN) emerged as the major customer of France and the USA, probably because of her conflicts with China. Saudi Arabia and India remained the largest weapon receivers in 1992-1999.

By comparing Figure 1.6(a) and Figure 1.6(b), we can see that the attribute clusters and the countries' relative positions in the visualizations remain almost the same. This indicates that, in



(a) The 1983-1991 network



(b) The 1992-1999 network

Figure 1.6: Visualizations of the military expenditures and arms transfer network before and after the cold war.

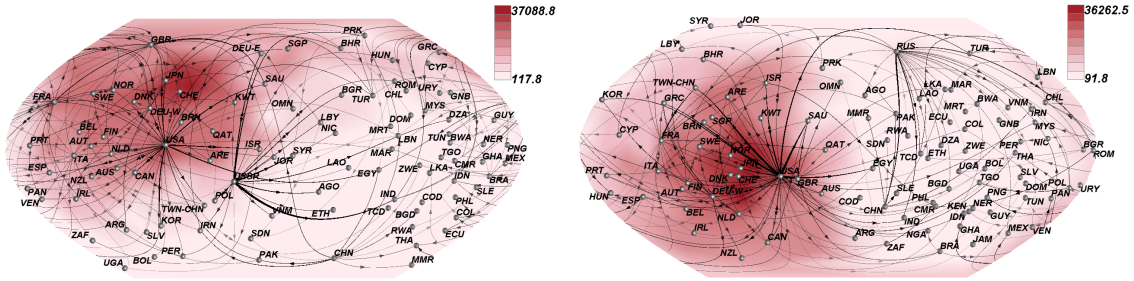
general, there are no substantial changes to the countries' military spending behavior. Country that experience the biggest changes was Soviet Union/Russia, which can be observed by her position changes in the two visualizations. In the 1983-1991 network, she was in the center of high military spending countries while in 1992-1999, she moved to the left towards the low spending countries.

Careful readers may notice that most of the edges in both networks are single directed and their widths are not the same at the two ends. These mean that the weapon trading were highly

imbalanced and most the countries were depend on a few number of weapon suppliers. On the other hand, there was not much trading between the five major weapon suppliers, which is very different from the cereals and manufactured metal trading networks.

1.3.4 Changes of Attributes Distribution

GNP per capita

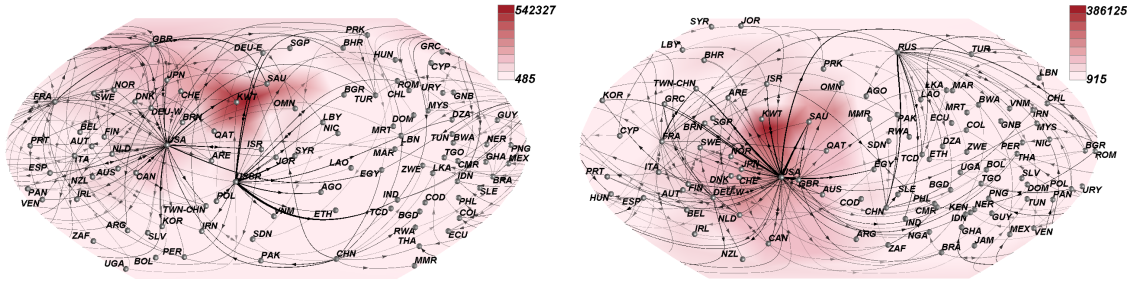


(a) The 1983-1991 network (b) The 1992-1999 network

Figure 1.7: Component planes of GNP per capita in two periods.

Component planes of GNP per capita at the two periods are shown in Figure 1.7. In the 1983-1999 network (Figure 1.7(a)), the high income countries are mapped to the upper left region. The same set of countries are mapped to lower left region in the 1992-1999 network, (Figure 1.7(b)). As we can see, the unequal distribution of wealth was unchanged in these two periods. The incomes of the richest countries (e.g. Japan, Switzerland and the USA) were more than 300 times of the poorest countries's (e.g. Ethiopia, Chad and Lao). The most noticeable changes was the income level of USSR/Russia whose GNP per capita was dramatically reduced from $11042 to $4855.

ME/AF



(a) The 1983-1991 network (b) The 1992-1999 network

Figure 1.8: Component planes of ME/AF in two periods.

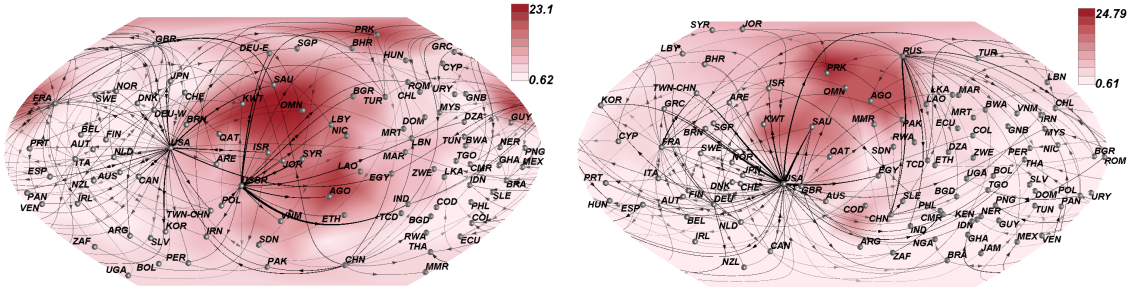
The value of ME/AF provides a general indicator of a country's military technological or preparedness level. As shown in Figure 1.8, the distribution of ME/AF is very similar to the distribution of GNP per capita, which means that soldiers in the the high income countries are generally more well-equipped than in the developing countries. However, countries with the highest values of ME/AF are from the Persian Gulf area instead of the richest countries:

- During 1983-1991, the biggest military spender was Kuwait who paid an average of $542327 per soldier. She was followed by Saudi Arabia whose ME/AF was $327880. The two key weapon exporters — the USA and the USSR — ranked the 4th and the 9th respectively in terms of ME/AF. The country with the lowest ME/AF value was Guinea Bissau (GNB) who spent only $485 per soldier.

- In 1992-1999, although Kuwait dramatically reduced her value of ME/AF to $386125, she was still the world's NO.1 military spender. As indicated by the expanding trading volumes, the USA increased her expenditure per soldier to $183500 which was the second highest in the world. Due to the economy downturn, Russia cut her ME/AF to $35488 and her ranked was dropped to the 30th in the world. The value of military expenditure per soldier was almost double for Guinea Bissau ($915), but she remained the country that invested the least amount of money on military.

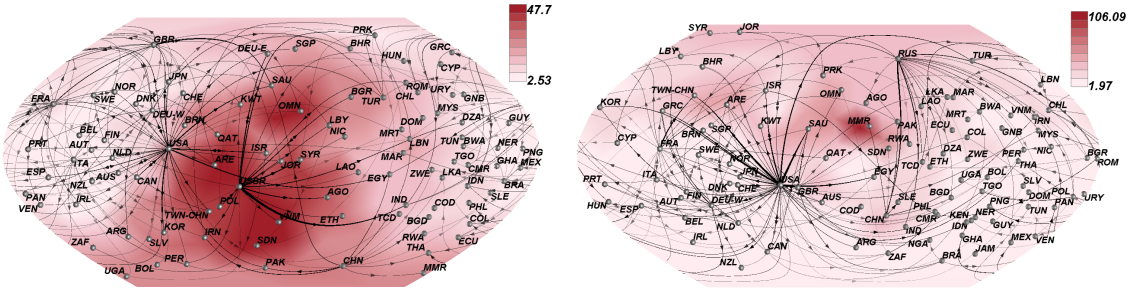
The Military Burden: ME/GNP and ME/CGE

Component planes of ME/GNP (Figure 1.9) and ME/CGE (Figure 1.10) reveal that countries mapped to the middle of the visualizations had highest military burden. In addition, the developing countries had heavier military burden than the developed countries.



(a) The 1983-1991 network (b) The 1992-1999 network

Figure 1.9: Component planes of ME/GNP in two periods.



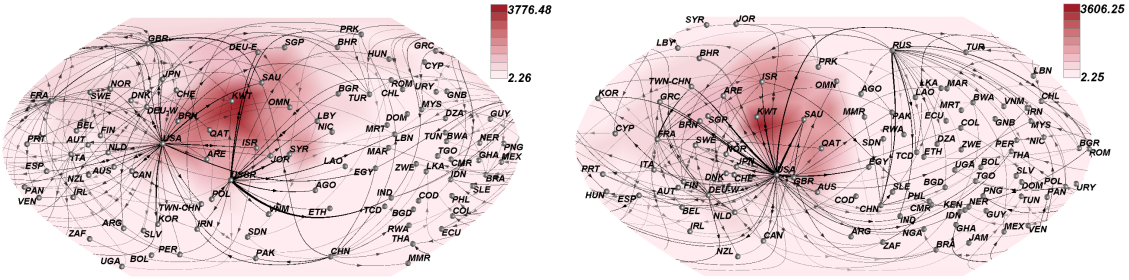
(a) The 1983-1991 network (b) The 1992-1999 network

Figure 1.10: Component planes of ME/CGE in two periods.

We will first discuss the ratio of ME/GNP. During 1983-1991, developed countries like Japan, Great Britain and Italy only invested around 3% of their GNP on armies. The ratio of USA and the USSR was 5.94% and 12.37% respectively. On the other hand, the military expenditure of countries in the Persian Gulf region (e.g. Oman, Kuwait, Saudi Arabia) account for more than 20% of their GNP. Some low income such like North Korea and Angola still direct over 15% of their resources to maintain their military. The distribution of ME/GNP did not have big changes in 1992-1999. Exceptions include Russia who reduced her ratio to 6.4% and North Korea who further increased her ratio to 24.79%. Therefore, North Korea became the country with highest military burden in 1992-1999.

The trend that the developing countries had heavier military burden are more obvious in the component planes of ME/CGE(see Figure 1.10). During 1983-1991, the ratios of the wealthy developed countries were less than 10% except those of the leading military exporters' (around 20%). Countries of the Persian Gulf area (e.g. Kuwait, Saudi Arabia, United Arab Emirates) spent more than 30% of their central government expenditure to military. However, these figures are non-comparable to ratios of the developing countries'. For example, the USSR and North Korea direct more than 45% of their central government expenditure on military which were the highest in the world. After 1992 (see Figure 1.10(b)), most countries reduced their ratio of ME/CGE. For example, both Russia and North Korea cut the ratio to less than 30%. The value ME/CGE remained almost the same for the Persian Gulf countries. However, Myanmar (MMR) dramatically raised her ratio from 24.02% to 106.09% which was the highest in the world. The sharp increase was believed to be caused by Myanmar's political crisis began at 1988. The military junta gained control over the entire country and armed forces [1].

ME Per Capita



(a) The 1983-1991 network (b) The 1992-1999 network

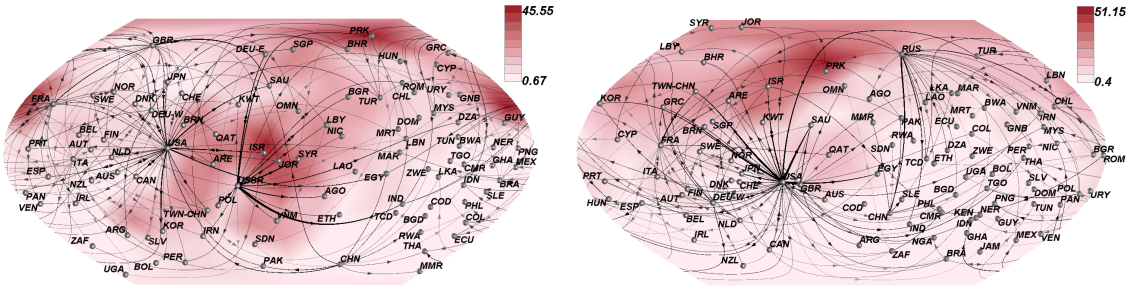
Figure 1.11: Component planes of military expenditure per capita in two periods.

As mentioned in Section 1.3.1, the variable ME per capita measures the cost of security/defending. Figure 1.11 reveals that people living in the developed country paid more money to maintain security than people in the developing countries. Again, the security costs were highest in the Persian Gulf region. During 1983-1991, the top four countries are Kuwait, Israel, Qatar and Saudi Arabia. On average, each citizen of Kuwait paid $3776.48, which was higher than 52 countries's annual individual income (GNP per capita). Such high security cost was caused by the constant disputes around the Persian Gulf region. For instance, the Iraq-Iran war was lasted from 1980 to 1988, the Persian Gulf War began at 1991, the territotial disputes between Qatar and Bahrain, Yemen and Saudi Arabia etc [8]. The country with the lowest defending cost was Ghana in which each people only paid $2.26 annually for their armies.

In 1992-1999, countries in the Persian Gulf region still have the highest defence cost. As indicated by the variation of colors, Russia's ME per capita was dramatically reduced from $1365.03 to $317.75. Ghana's value of ME per capita was slightly increased to $3 per person and Niger became the country with lowest security cost ($2.25).

Armed Forces Per 1000 People

Armed forces per 1000 people measures the relative number of soldiers a country required to maintain its internal or external security. As shown in the component planes (Figure 1.12(b)), in both period, countries in the unstable Persian Gulf region had to maintain larger size of army than other countries in world. However, North Korea was the country with largest armed forces. In 1983-1999, she had 45.55 soldiers per 1000 people. The number was increased to 55.15 in 1992-1999. This change was probably cause by the strained relations with China who normalized diplomatic relation

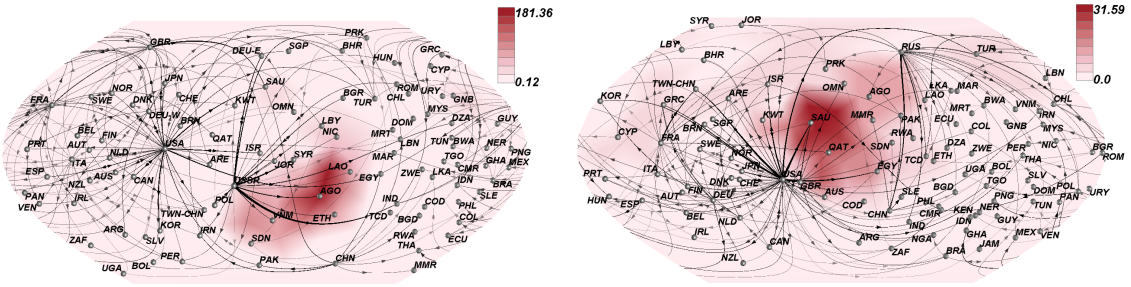


(a) The 1983-1991 network (b) The 1992-1999 network

Figure 1.12: Component planes of armed forces per 1000 people in two periods.

with South Korea in 1992. Other countries actually reduced their armed forces after the cold war. For example, Israel had 45.54 soldier per 1000 people in 1983-1991, which was reduced to 33.51 in 1992-1999. The USA cut her army size from 9.17 to 6.24 soldiers per 1000 people while Russia reduced the number from 13.34 to 8.88.

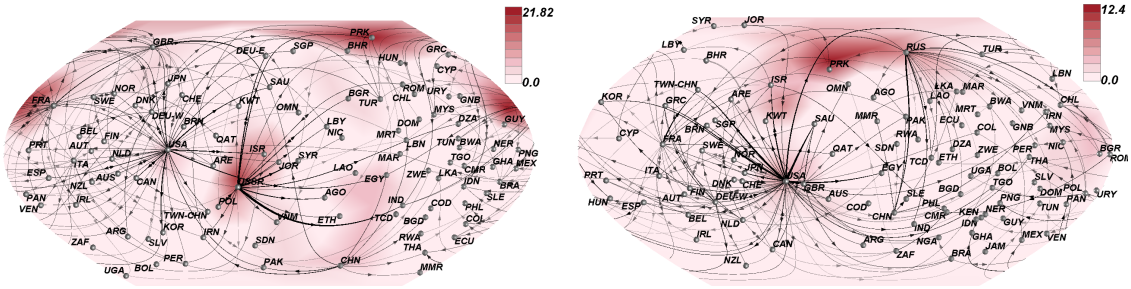
The Dependence/Importance of The Arm Industry: military import/export to non-military import/export



(a) The 1983-1991 network (b) The 1992-1999 network

Figure 1.13: Component planes of weapon import in two periods.

We will first discuss the ratio of military to non-military import. This indicator measures the dependence level of a country on other countries for weapons. The previous component planes show that Persian Gulf countries had the highest values in most military expenditure indicators, which may give us an impression that their ratio of military to non-military imports must also be the highest. The component plane of 1983-1991 shows a very different situation (see Figure 1.13(a)). The dependence level of the Persian Gulf countries ($< 55\%$) were far behind several African and Asian countries such as Angola (181.36%), Ethiopia (73.93%) and Viet Nam (71.54%). Angola's weapon import was almost twice of her non-military imports. If we look back in the history, throughout the



(a) The 1983-1991 network (b) The 1992-1999 network

Figure 1.14: Component planes of weapon export in two periods.

1980s and early 1990s, Angola was in an intensified civil war as the USSR and the USA poured extensive military resources into the country [12]. The war was considered one of the largest Cold War conflicts of the developing countries. This explains the high weapon import ratio of Angola in 1983-1999. After 1991, with supervision of the United Nations, several cease-fire agreements were signed and the war was finally settle in 2002. Therefore Angola's ratio of military to non-military import was significantly reduced to 11.11% in 1992-1999. In the mean time, Ethiopia and Viet Nam also dramatically cut their military import. Their ratio became 4.38% and 1.08% respectively. The Persian Gulf countries became nations that most relied on foreign weapon imports after the cold war. Saudi Arabia's military to non-military ratio was 31.59% which was the highest in the world. In both periods, weapons import ratios of the major weapon exporters (e.g. the USA, the USSR/Russia, Great Britain, France and China) were less than 2%.

As to the ratio of military to non-military export (see Figure 1.14), most of the countries have very low export rates. In both periods, the weapon export ratios of the Persian Gulf countries (e.g. Kuwait, Saudi Arabia and United Arabia Emirates) were less than 0.1% and more than 40 out of the 97 countries had zero military export rates. This means that their weapon industry were not comparable to the top military suppliers'. Interestingly, the major weapon suppliers did not have the highest ratio of military to non-military export. In 1983-1991, except the USSR (18.83%), ratio of the other four leading weapon suppliers were all less than 6%. Country with the highest military export ratio was North Korea (21.82%) who mainly sold weapons to Iran, Egypt and Syria. After the cold war, the weapon export ratio of North Korea was reduced to (12.40%) which was still the highest in the world. All major weapon suppliers lowered their weapon export ratio. For example, Russia's weapon export ratio became 4.24% and ratio of the USA was 4.53%.

1.3.5 Discussion

The above analysis reveal several characteristics of armed transferred network:

- There are five major weapon suppliers in the world: The USA, the USSR/Russia, Great Britain and China. Most of countries in the world are depending on them for weapon supplies.
- Unlike the trading of common commodities where core countries trade heavily with each other, the trading between the top weapon providers are sparse.
- Before the cold war, the USA and the USSR were competitive rival in the international weapon market. The USA mainly provided weapons to developed countries and the USSR to the developing countries. After the cold war, Russia experienced economic decline and significantly cut her military expenditures. She continued to supplier weapons to developing countries but the USA became the dominant arms providers.
- On average, the high income countries paid more money for their military establishments. However, the military spending only account for a few percent or their GNP or CGE. The developing countries have much greater military burden and higher security costs, especially for the Persian Gulf countries and those countries with political crisis.
- After the cold war, most of the countries cut their armed forces except North Korea. North Korea remained the country with the largest number of soldiers (relative to her population). She had the highest military burdens in the world.

1.4 Conclusion

This chapter visualized four international trading networks. It aimed to demonstrate the effectiveness of the hybrid visualization in helping viewers understand multivariate networks.

We first introduced what the economic researchers's want to find in the international trading networks. They are interested in the trading patterns of different types of countries, how the trading patterns change with time and the correlation between the countries' attributes and trading levels.

The first application visualized the trading of cereals and manufactured metal between 80 countries in 1994. The hybrid visualizations clearly revealed the different trading patterns of countries belonged to the core, semi-periphery/periphery. Countries' attribute similarities are shown by their relative positions and color region on the representations. In addition, by examining the component

planes, we are able to see the correlation between the countries's attribute and trading patterns. Countries with high incomes are more likely to establish international trade, which is consistent with the result calculated by the economic researchers.

The second application visualized the military expenditure and armed transferred networks in two periods (1983-1991 and 1991-1999). The hybrid visualizations disclosed several characteristic of the weapon trading network. For example, the international weapon market was dominated by a few weapon suppliers especially the USA and the USSR/Russia. Unlike the common commodities trading networks, the key weapon suppliers were not major trading partners. In addition, by comparing visualizations of different periods, we were able to found several changes in the weapon transfer networks between the two time period. For instance, after the cold war, Russia experienced economic decline and her role as leading weapon provider shrank. In the mean time, trading volume of the USA increased significantly and she became the biggest weapon provider.

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