Chapter 15

GLOBALIZATION AND INTERNATIONAL TRADE

Utilizing Insights from Graph Theory

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Introduction

Individuals are mutually linked within an estimated six degrees of separation (Watts, 2003).[1] The notion of such an intertwined world has fascinated many, and serves as a fundamental principle for new and exciting technologies. Inventions ranging from the Internet to the cellular phone make use of a deep and persistent interconnectedness. In turn, these inventions create and destroy new links amongst people, as do many other phenomena such as disease, natural disasters, and trade. Measuring the quality and the quantity of these links between individuals has been a popular pursuit of sociologists.[2] But what can be learned when one implements those same empirical techniques at other societal and political levels?

In this chapter, we explore a new approach to identifying the complex hierarchical order that shapes international relations. By applying techniques from graph theory to examine relationships between countries, we break from a long line of international systems' scholars to take a new path, a path that should help us better understand the dynamic interactions of nations. We approach our analysis along two layers of the international system: the *macrolayer*, or overarching structure of the international order involving all nations, and the *submacrolayer*, whereby groups of nations interact.[3] We conclude with a brief discussion on the applicability of our methodology,

[1] The authors would like to thank Hanyin Lin for her research assistance, and Ramy Arnaout, Nazli Choucri, and Kenneth A. Oye for their advice and feedback.

[2] Watts (2003) provides a good review of the sociological research on interconnectedness.

[3] The third and final layer is the *microlayer*, involving dyadic relationships between two countries.

N. Choucri et al. (eds.), Mapping Sustainability: Knowledge e-Networking and the Value Chain, 301–336.

and how our findings may be used to tackle other questions in international relations.

Theoretical Perspectives of the International System

Scholars in international relations have been extensively engaged in analyzing systemic effects in international politics. Given the broad corpus of literature on this issue and the seemingly perpetual debate over certain definitions and conjectures, we shall consider the literature while avoiding entrance into any particular arguments. In *Man, the State, and War*, Kenneth Waltz introduces three images for analyzing international relations (1954). Each image includes an area of study that can affect world politics. The first image includes individuals, the second image includes the domestic institutions of the nation, and the third image involves the international structure, or system. Waltz's two chief goals are to justify realism in the context of international politics (that nations are driven by power-maximization rather than by simple desires for peace and harmony), and to stress the importance of research in the third image, and more broadly, for understanding systemic patterns of international relations.

Kaplan offers a framework for exploring international systems by considering six such states of equilibrium of the international order; note that only one of these over-arching systems can exist at any given time (1957: Chapter 2):

The Balance of Power System: Exists in a null political subsystem (anarchy). There are at least five "essential" actors/nations in a Balance of Power System that implement the "essential" rules which govern the characteristic behavior of the population of actors.

The Loose Bipolar System: Formalized, supranational actors as well as national actors both participate in such a system. Two subclasses of supranational actors must exist to form the bipolar system. During the time of the Cold War, NATO and the Communist blocs formed a Loose Bipolar System.

The Tight Bipolar System: Similar to the Loose Bipolar System except all national actors belong to one of the subclass supranational organizations. Such a system would resemble the international system during the Cold War if all of the members of the Third World had allied with NATO or the Communists.

The Universal System: The previous three systems include an anarchic political order; the universal system assumes that national actors are governed by a universal actor. If the United Nations and the World Trade Organization had greater power in the contemporary international system, we would call our modern-day international system a Universal System.

The Hierarchical System in Directive and Non-Directive Forms: The Hierarchical System is one in which a universal power rules directly over the people, with no independent national political systems. In its Non-Directive Form, the Hierarchical System is a world-wide democracy; in its Directive Form, the system is authoritarian.

The Unit Veto System: The Unit Veto System can occur when either national actors or bloc actors control the system. The Unit Veto System stipulates that all members have the capability of destroying each other, suggesting that all members are equally powerful.

While Kaplan was writing in the 1950s and 1960s, understanding the over-arching structure of the international system again became popular following the end of the Cold War.[4] Richard Ned Lebow observes that due to the collapse of the USSR, "prominent realists maintain that a shift is under way in the international system from bi- to multipolarity" (1994: 249). For Lebow, a Multipolar System is most similar to a Balance of Power System, except that in a Multipolar System, anarchy could be supplanted by a universal actor. Contending that the paradigm of realism requires the condition of international anarchy, Lebow calls for theorists to explicitly state which system paradigm their theories exist within, and to search for theories that would hold across multiple systems. Lebow explains that theories with carry-over capacity across the various types of international orders form the backbone of neorealism (Lebow, 1994).

Kaufman further considers the nature of international orders in the context of neorealism (1997). Kaufman explains that simply because the 20th Century has been dominated by bipolar and multipolar systems does not mean that these are the only two such systems in existence. History is replete with examples where the international order is best described on a complete gradient, from Hegemony (Universal) to fragmented and wholly separate smaller units (Kaufman, 1997). More importantly, Kaufman explains that "the causes of system variance include not only power-balancing dynamics, which work only imperfectly, but also principles of unit identity [and] economic interdependence ..." (Kaufman, 1997: 200).[5] As a result, Kaufman calls for analyzing economic interdependence and international sub-systems within the context of the overarching international system.

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[4] Between Kaplan and Lebow, several prominent scholars have considered the meta-structure of the international system, coming up with a whole slew of various orders. One system that deserves mentioning is that of Hegemonic System, where one national actor maintains stability across the international system. However, the Hegemonic System is really a derivative of the Universal System. The key readings on the Hegemonic System are Gilpin, 1981 and Keohane, 1984.

[5] Kaufman also calls for investigating technologies for governance and how they affect the international order. This topic encompassed the thrust of a class the author co-taught with several other GSSD affiliates in January, 2006.

To summarize, some nations are stronger than others, suggesting hierarchies exist in the international system. As different alliance structures exist, some nations are also more closely connected with one another. This *homophily*, or level of interconnection among groups of countries, varies across the international system.[6] Moreover, the hierarchies of the macrosystem and the levels of homophily of the various subsystems vary over time. These systemic variations may have a variety of consequences, leading to several questions such as: does a system with a Balance of Power hierarchy tend to be peaceful compared to an imbalanced hierarchy? Are systems with bipolar hierarchies more peaceful than systems with multipolar hierarchies? Do systems with tight poles (with high homophilies) tend to be more peaceful than systems with loose poles (with low homophilies)? As we shall explain in the next section, to answer these questions empirically, we must consider alternative approaches to identifying and analyzing the international system.

Previous Empirical Investigations of the International System

Previous empirical examinations pertaining to these questions have exhibited several problems. Previous research, and the corresponding flaws endemic to most of this work, is best exemplified by Bruce Bueno de Mesquita and David Lalman in "Empirical Support for Systemic and Dyadic Explanations of International Conflict" (1988). Using both systemic and dyadic statistical techniques, Bueno de Mesquita and Lalman's research suggests that systemic differences do not seem to affect international conflict. In contrast, individual country calculations of expected utilities of war are far better predictors for the breakout of international conflict.

While Bueno de Mesquita and Lalman should be applauded for undertaking such an ambitious project, their research methodology could be improved in several ways. First, Bueno de Mesquita and Lalman constrain their analysis of the international system only to European countries. A more rigorous approach should include all of the countries in the international system. Second, Bueno de Mesquita and Lalman do not consider different levels of the international system. While purportedly conducting an analysis of the entire international system, their analysis only includes countries that are deemed to be major powers, meaning that Bueno de Mesquita and Lalman are only examining the highest part of the hierarchy of interactions in the international system. Equally important, Bueno de Mesquita and Lalman do not consider the layers of the international system. By "layers," we mean that the international system is comprised of interactions at the *microlevel*,

[6] The terms "hierarchy" and "homophily" have been adopted from Dodds, Watts, and Sabel (2003). Bueno de Mesquita and Lalman did not use them, despite expressing similar ideas.

whereby countries interact in a one-on-one fashion, at the *submacrolevel*, where countries join regional blocs or alliances, or at the *macrolevel*, where global accords and worldwide institutions shape international interactions (which we have previously identified as the overarching international system). Bueno de Mesquita and Lalman explore microlevel conditions while conducting their dyadic analysis, but they refrain from discussing what they mean by "international system," and what layer they are examining in their systemic analysis. There is a better way to determine the systemic structure of the international order, and what effects these system properties may have.

15.1 Graph Theory: an Alternative Approach

While scholars in international relations have theorized, and even empirically investigated the international system, sociologists, scientists, and engineers have increasingly engaged in studies of systems pertinent to their own domains and disciplines (Newman, 2003).[7] As scholars recognized the commonality of studying systems, a new mode of analysis grew out of their collaborations. Known as *graph theory*, it now stands as a robust – but still developing – arena within academia.[8] More importantly, techniques of graph theory offer a way of approaching the three levels of the international system at once, by using dyadic relationships to identify and explore submacro and macrosystem structures.

Not surprisingly, one of the chief pursuits of graph theorists rests in analyzing system stability and the spread of system instability. Albert and Barabási examine the stability of certain types of systems and networks in the context of the Internet and the World Wide Web (2002); Maslov and Sneppen investigate stability in protein networks (2002); Dunne, Williams, and Martinez consider system stability in the network of food webs (2002). Indeed, while international relations scholars such as Robert E. Keohane complain that predictability is elusive as "[t]oo many factors interact in complex ways to produce the results we see," including "[r]andom shocks

[7] Newman's "Structure and Function of Complex Networks" represents the best compendium of graph theory (2003). Citing 429 other references, Newman leaves few stones unturned.

[8] Graph theory is also known as network theory. While the terms are used interchangeably throughout the literature (see Newman 2003 for example), we anticipate that in time, network theory will come to classify relationships where flows between actors are involved, while graph theory will describe relationships between various actors. If we accept such a dichotomy, both the fundamental concepts and the mathematics of network theory and graph theory are nevertheless tremendously similar, making such a distinction a moot point. However, since we are primarily focused upon relationships of trade rather than flows of trade, we shall describe our approach as a graph theoretic approach.

[that] disrupt the system," graph theorists do not shy away from this challenge (1997: 150). Instead, they embrace it. The attitude that complexity needs be better understood rather than avoided guides our project, as it is necessary for execution of a proper graph theory methodology.

In order to better understand system stability and instability in the context of sustainability, we seek to identify the structure of the international system. Recognizing that the international system includes a diverse and diffuse set of relationships among an equally diverse and diffuse set of actors (states), we seek to identify the system structure across of one type of common interaction: international trade.[9] Further recognizing that a whole host of non-country actors – including individuals, grassroots movements, multinational corporations, and other non-governmental organizations – all affect international politics, we contain our analysis of the international system exclusively to relationships between countries. While other elements of the international system are important, nations form the backbone of international politics, and it is their relationships among themselves and with the overall structure that we are chiefly interested in identifying (Gilpin, 1981: 26; Kaufman, 1997).

As we alluded to earlier, there are three layers in the international system of trade: the micro (relationships between two countries), the submacro (relationships between more than two countries, but fewer than all countries), and the macro (relationships between all countries). In analyzing trade, much work has already been conducted across all three levels. Micro/dyadic/bilateral relationships have been examined by several scholars of international relations, most recently by Beck, King, and Zeng (2000; 2004) and by Bennett and Stam (2000).[10] At the opposite end of the spectrum, macrorelationships have been considered by Waltz (1954) and Walt (1985), to name just two of many theorists. And between micro and macro, submacrorelationships have been studied in terms of geographic country groupings (Schirm, 2002), in terms of political and military alliances (Krebs, 1999), in terms of culture (Huntington, 1996), and in terms of economic bonds, especially by way of trade blocs (Mansfield and Milner, 1999).

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[9] We shall later explain why we chose trade over other measures. To be clear, there are several options: for instance, it is widely believed that the Asian financial crisis was not caused by changes in trade, but rather by changes in capital and investment flows. Modeling such other economic structures would also be a useful and worthwhile project.

[10] Each of these works use micro relationships to explore the causes and consequences of dyadic conflict. Beck, King, and Zeng's work received significant backlash as they were also introducing a new methodology (by way of neural network analysis) to interpreting long-standing theories. While neural network analysis and graph theory are computationally and methodologically distinct, with the introduction of graph theory, resistance should also be expected from the old-guard.

15.1.1 Key Concepts

If techniques in graph theory can help us improve both submacro and macrosystemic research, then we need to clarify and define the key methodological concepts. To begin, a *graph*, or a *network*, is simply a representation of a system.[11] In our case, the network includes all countries and their relationships in a given time period. A *node*, also known as a *vertex*, represents an individual component of the system.[12] For our purposes, a node represents a country within the international system. Interactions among the nodes can be considered as the unit of analysis. These interactions are usually expressed as an *edge*, which represents a relationship between two nodes.[13]

An edge may be *directed* or *undirected*. A directed edge represents a flow, while an undirected edge simply depicts the existence of a relationship between two nodes. A directed edge is usually displayed with an arrowhead showing the direction of the relationship; an undirected edge is simply a line connecting the two nodes.[14] For example from international politics, a directed edge could represent the flow of migrants from one country to another, while an undirected edge could represent the existence of diplomatic relations between two nations. In Figure 15.1, a network with its basic components is presented; note that the edges are undirected.[15]

Graph theorists frequently discuss the number of *degrees* of a certain node. Degrees correspond to the number of relationships that a certain node enjoys. The number of degrees can be counted by counting the number of edges of a node. In Figure 15.2, Nodes A, C, and E all have only one degree (A–F, C–B, and E–D, respectively). Node B has two degrees (B–C and B–F), Node D has two degrees (D–E and D–F), and Node F has three degrees (F–A, F–B, and F–D).

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[11] Most of the terms and descriptions have been identified and adapted from Newman (2003), but they are all among the standard lexicon in graph theory. Some of these terms are presented in this section, but are not used until later sections. We group the terms together because it is helpful to make one repository of all the terms for ease of reading.

[12] Graph theory is plagued by multiple labeling of similar concepts. In physics, a vertex is known as a *site*; in sociology a node is often referred to as an *actor* (Newman, 2003).

[13] Some individual edges can connect more than two nodes, but these are rare and are typically contained to very complex graph theory. In physics, edges are also known as *bonds*; computer scientists call edges *links*; sociology labels these connections as *ties*. For an excellent summary of the concepts of graph theory that both a novice graph theorist and a network veteran would appreciate, read Newman's "The Structure and Function of Complex Networks" (2003).

[14] Any existing relationship between two nodes is either directed or undirected.

[15] Directed edges are oftentimes known as arcs, and they are represented as arrows (rather than lines) to show directionality.

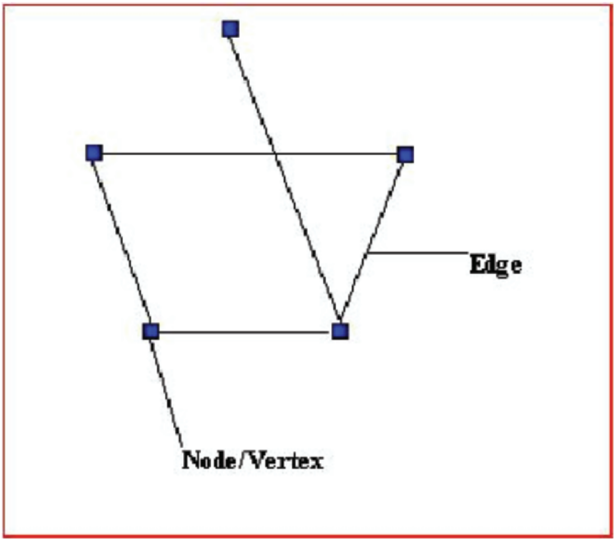

Figure 15.1 **A labeled network.**

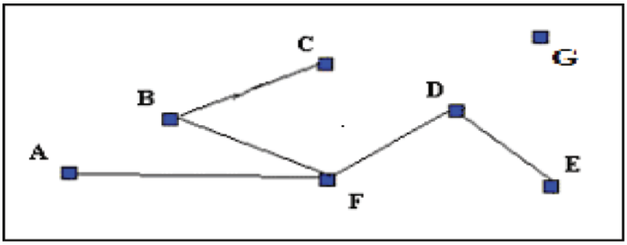

Figure 15.2 **A network with nodes A–G.**

Sometimes one node may be included in the system, but may not connect to the larger grouping. Node G is one such example, with zero degrees. In practice, one would be hard-pressed to identify a country entirely isolated from the rest of the modern-day network, but it is nevertheless theoretically possible.

In a previous section, we discussed several possibilities of the macrosystem, derived from the international relations literature, and one can imagine a list of possibilities even beyond those presented. In graph theory, there is a corresponding set of possibilities, each of which may capture the structure of the macrosystem in the context of the international system. There are at least two broad categories of network types, with a whole range of network subsets in between.

The first type of network in the graph theory literature is the *Random Network* (Newman, 2003; Barabási and Albert, 1999). A Random Network is one in which the degree distribution is Gaussian, or evenly distributed. In a Random Network, a hierarchy could exist with certain nodes playing more important roles than others, but the bulk of the nodes have a similar set of degrees. Hence, Random Networks have interactions taking place across a global arena: there are few submacrogroupings, if any. In Figure 15.3(a) we present such a network structure.

In contrast, a Scale-Free Network is one in which the degree distribution follows a Power-Law, where most nodes have few degrees while just a few nodes exhibit a high number of degrees. A Scale-Free Network tends to be dominated by submacrointeractions. It must also have a hierarchical structure, as certain nodes are more central to the network than others. These types of networks have recently received special attention by theorists as "citation networks, the World Wide Web, the Internet, metabolic networks, telephone call graphs and the network of human sexual contacts" all appear to be Scale-Free Networks (Newman, 2003: 188). In Figure 15.3(b), we display a Scale-Free Network. Notice the shaded nodes, which indicate nodes that are more central to the system structure than the peripheral nodes surrounding them.[16] All networks that have hierarchies involve such Hubs and Spokes, where certain nodes are central to the system structure (Hubs), while others are at the fringes of the system structure, both literally and figuratively (Spokes).

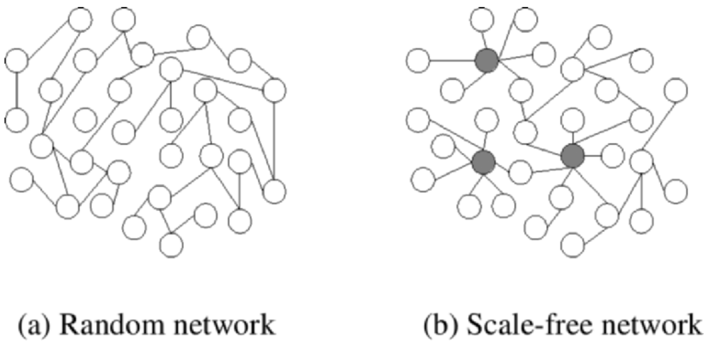

Figure 15.3 **(a) A random network versus (b) a scale-free network. Source: Wikipedia, 2006.**[17]

[16] Discussions of core- and peripheral- countries are common in international relations literature (Wallerstein, 1976; Denemark et al., 2000). However, such terms have developed a pejorative connotation as they are frequently associated with colonization and imperialism. In order to jump this semantic hurdle, we shall utilize their graph theoretic terms: Hubs and Spokes.

[17] We realize that using Wikipedia should be done with caution, but they present one of the clearest images of a random versus a scale-free network. The image is located in *Scale-Free Networks* at http://wikipedia.org/ (accessed 2006).

15.2 Identifying the Type of System Formed by Trade

To test which type of network best represents the macrosystem, we gathered export data from 1962 to 2003 from the UN Comtrade Database.[18] We selected trade data for this experiment for three reasons. First, trade relationships are easy to measure.[19] Data is easily accessible, and unlike war or conflict, trade relationships are generally agreed upon. Second, trade is one of the most important relationships in international relations: all countries engage in some level of international trade. At the same time, with economic globalization, the World Trade Organization, and the unification of currencies in Europe, patterns of trade have undergone profound changes over the last 40 years. Understanding how these changes have affected the international system is worthwhile. Third, trade is a strong proximate indicator for power relationships between countries and power relationships are the fundamental building blocks of the international system at large (Hirschman, 1980). In other words, we may be analyzing the international system of trade, but such analysis helps us better understand the international economic system, as well as the international system in general.

Despite the advantages of using this dataset, the most fundamental threat to the validity of our findings still rests in the Comtrade dataset. We have to assume that the Comtrade dataset provides all trade relationships in the international trade system. The exclusion of a singular country from our initial runs could potentially have profound and dramatic implications for our findings. By way of validation, we also consulted international trade datasets from other prominent political economists, and we are currently considering the merits and demerits of the various datasets. However if Comtrade is exhaustive, what follows are several empirically-grounded results that could have profound implications for international relations systems theory. If Comtrade is not exhaustive, the value of "walking through" the methodology should also be appreciated.

In our analysis of the macrosystem, all relationships are undirected. This means that we are studying interactions not in terms of flows between countries, but instead we are looking at the aggregate numbers and sizes of the interactions themselves. The database itself provides dollar value relationships

[18] Behram Mistree extracted the data from the database by constructing a computer program that interfaced with the United Nation's website using standard http protocols. The program requested, parsed, and stored information from the site.

[19] We are analyzing relationships over time, but we want measures that are time-appropriate. Imagine receiving a measure that Country A received six million dollars in capital from Country B in a given year. Due to the tremendous fluidity of capital, this number might become inflated as over the course of the year, some of the capital given to Country A is returned to Country B, only to be again returned to Country A. Therefore, measuring relationships in terms of capital flows does not work.

between all countries. The level of detail of the UN Comtrade data is actually quite impressive. For instance, Comtrade lists that Egypt exported $575 worth of goods to Bermuda in 2003. However, Egypt's exports to Bermuda account for a negligible fraction of its overall exports. Afraid that the inclusion of such superfluous relationships may obfuscate the fundamental dynamics we are attempting to uncover, we only include "major" export flows.

For the purposes of this chapter, we define "major" in such a way that an export flow will only be included when Country A receives a quantity of exports from Country B that is in the top 70% of total exports for Country B.[20] In as much as quantitative analysis is an art, we recognize that such a cutoff introduces a level of subjectivity, but this subjectivity is minimal. More important, this cutoff is rendered consistently throughout the analysis.

To discern results, we shall use two tools: visualization and statistical analysis. Visualizations are one of the key aspects of graph theory. Newman explains that "[t]he human eye is an analytic tool of remarkable power, and eyeballing pictures of networks is an excellent way to gain an understanding of their structure" (Newman, 2003: 170–171). Beyond graph theory, Ortiz discusses the potentials of visualization as a methodology in political science, as visualizations may reveal patterns and relationships which would have gone undetected using traditional analysis (2005). When implementing visualizations as a methodology, however, the researcher must be wary. McGrath and Blythe discuss the dangers of visualizations as methodologies as visualizations may appear different to different people, conveying different meanings and relationships to different researchers (2004). Fortunately, graph theory has recently begun to adopt empirical techniques as complex networks with millions and billions of relationships are now common, and simply visualizing these networks with millions and billions of interconnections is relatively ineffectual (Newman, 2003). As a result, statistics are also being introduced to graph theory to better explain how components in complex systems affect one another.

There are several different ways of portraying networks. After reviewing several of these different ways, we decided to employ a *spring embedding function*, a special type of energy minimization function.[21] An energy minimization function plots the nodes with higher degrees in the center of the

[20] We believe that using 70% as the cutoff adequately strikes a balance between reducing the relatively minor data that would shroud the depiction of the macronetwork while preserving the general and major international trade trends. In the future, we shall conduct sensitivity analysis to see how greatly our results change with various cutoff rates.

[21] These figures were drawn using Netdraw with 100 iterations of the spring embedding function with distance between components equaling 5. Due to the nature of these graphing programs, images are never completely replicable, although the significant relationships should still stand out. After experimenting with another widely-available program known as Pajek, we found Netdraw to be more user-friendly.

image as the algorithm tries to minimize the distance of each edge while allowing a minimum set space between each node. As a result, Hub countries are centered in the image, while outer Spoke countries are placed at the fringe of the image.

15.2.1 Initial Results and Corresponding Implications

Using our methodology, we find that a Scale-Free Network best describes the system of international trade. In Figure 15.4 and 15.5, export relationships among the nations of the world are presented for 1965. Throughout the rest of this chapter, we will often show one network image without country labels and one with country labels so that the reader can first get a general feel for the system structure without being impeded by the country labels, and in the following graph, the reader can then identify the specific countries.

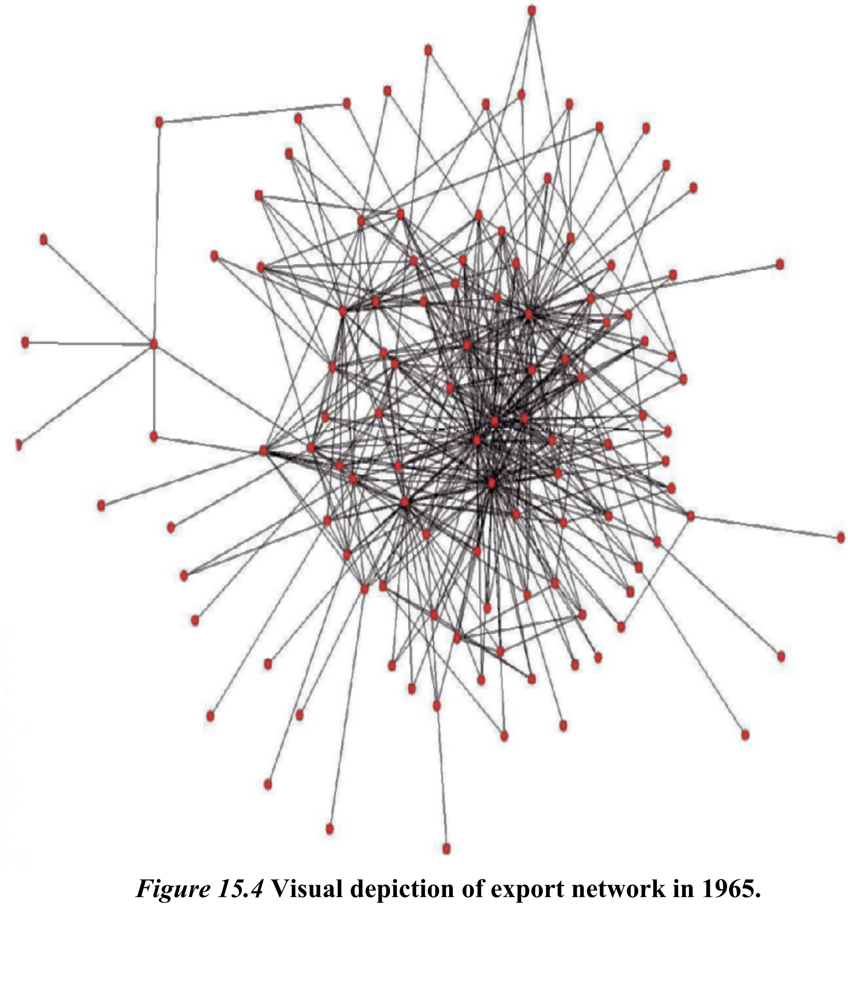

Figure 15.4 **Visual depiction of export network in 1965.**

In Figures 15.6 and 15.7, the state of the macrotrade network in 2000 is presented. Looking at Figure 15.4 in comparison to Figure 15.6, one can easily observe that the central part of the graph contains more nodes. Furthermore, those central countries are increasingly linked with one another.

However, before making any more observations about the changes between 1965 and 2000, two caveats are worth noting. First, since the Comtrade data only offers data for selected countries (typically only for countries that are members of the UN), some countries are not captured in these images, particularly the countries that are not somehow attached to the main network. Second, more countries are included in the dataset in 2000 than in 1965. There could be two reasons for such a condition: more countries may have joined the UN database and/or more countries have entered the macrotrade system. Despite these caveats, we can observe that the overall structure of the network has remained the same, with the center countries maintaining their importance to the overall network stability (if not assuming more

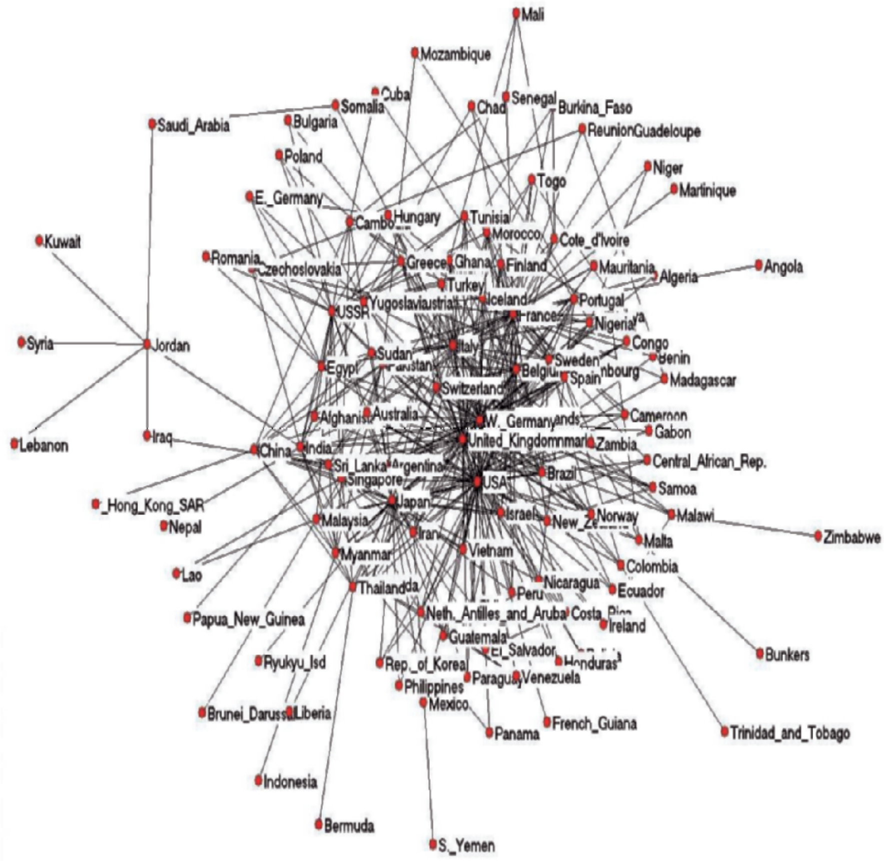

Figure 15.5 **Visual depiction of export network in 1965 (countries labeled).**

importance). The central region of the graph has also become more dense as the Hub countries seem to be trading more with one another and there appears to be more Hubs in 2000. Looking at Figure 15.5 versus the same network structure presented in Figure 15.7, it is not surprising that these central countries are among the world's richest: the United Kingdom, the United States, and West Germany are the three countries with the most degrees in 1965.

There are several other changes that are worthy of attention. Notice how China moves from an outer ring of trade in 1965 to the inner echelons of the network in 2000. In contrast, notice how Afghanistan's position in the international trade system declines as it moves from a semi-Hub location even more central than China to a remote corner of the graph by 2000.

In summary, these images alone do not confirm the existence of a Scale-Free Network, but they do show variations among countries that may suggest differences in trade-power as expressed by their macropositioning.[22] Note

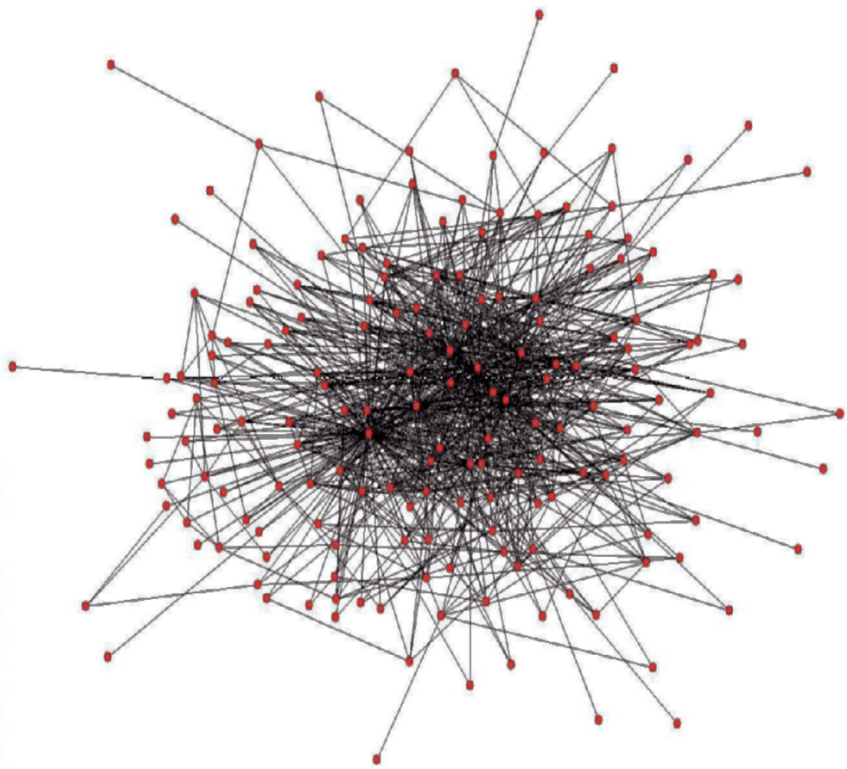

Figure 15.6 **Visual depiction of export network in 2000.**

[22] Power is used here in terms of Hirschman's conception of power, which is the ability of one country to coerce another (1980).

Figure 15.7 **Visual depiction of export network in 2000 (countries labeled).**

that the countries in the center – countries like the United Kingdom and the United States – are the ones which most trade relationships are dependent upon. Notice how the outer countries tend to have few relationships with other countries and are typically dependent upon only one or two countries.

15.2.2 Is the International System of Trade Scale-Free?

In order to determine whether the trade system conforms to a Scale-Free Network, we must inspect the distribution of degrees. In Figures 15.8 and 15.9, we display the distribution of degrees in 1965 and 2000, respectively.[23]

The x-axis represents the number of degrees of a nation and the y-axis represents the probability of a given country having that number of degrees.

[23] These charts were generated using Matlab. We also used Stata and Microsoft Excel for statistical work.

So in 2000, 2 out of 161 countries had 40 degrees exactly. Therefore, there is a 2/161 chance that if a country were selected at random, it would have 40 degrees. If we were to observe a Gaussian distribution, a Random Network

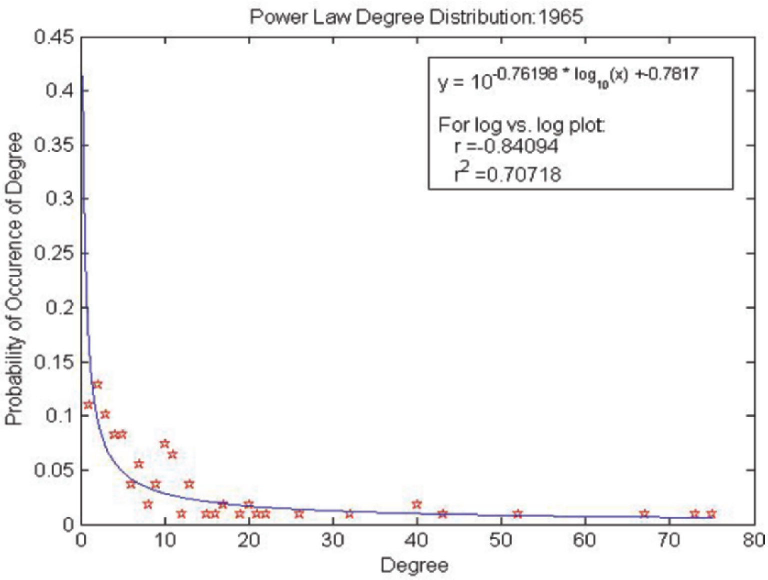

Figure 15.8 **Distribution of degrees in 1965.**

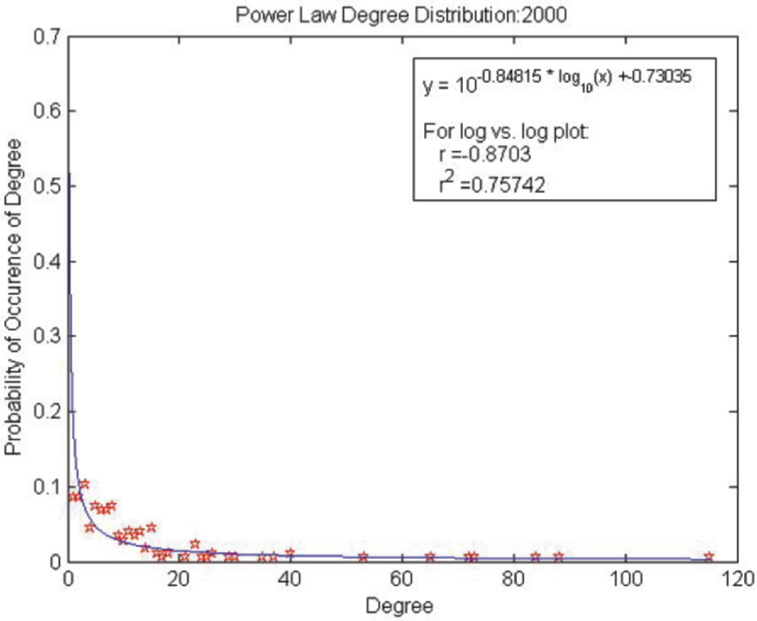

Figure 15.9 **Distribution of degrees in 2000.**

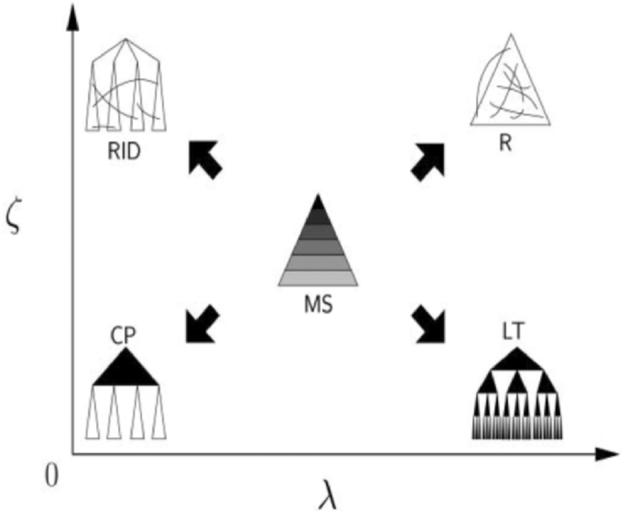

Figure 15.10 **Possible hierarchical structures. Source: Dodds et al. 2004: 12518.**

Would be in effect; if we were to observe a Power-Law distribution, a Scale-Free Network would be in place, with a definite hierarchy among nodes. We find that in both 1965 and 2000, the power-law distribution confirms that the macrotrade system conforms to a Scale-Free Network.

A Scale-Free Network suggests that the overall system is dependent upon some sort of hierarchy. There are several possible hierarchies outlined in the graph theory literature. Beyond Hubs and Spokes, Dodds, Watts, and Sabel have categorized five such possibilities for hierarchical network structures: *Random (R), Random Interdivisional (RID), Core-Periphery (CP), Local Team (LT), and Multiscalar (MS)* (2004).[24] These are presented in Figure 15.10.

The top two hierarchies are restricted to Random Networks. In a *Random Hierarchy*, links are distributed across a system so that flows and relationships need not necessarily follow a top-down structure. In a *Random Interdivisional Hierarchy*, there are apparent top-down relationships, but interactions take place across these cliques in a macromanner more so than a submacromanner. The bottom two hierarchies occur within Scale-Free Networks. In a

[24] Since Pool's days, MIT's Department of Political Science has played a relatively small role in social network analysis, but former department members are playing active roles in the domain nonetheless. For example, Charles Sabel was a professor at MIT from 1977 to 1995; according to his publications, however, he did not become involved in graph theory until joining the faculty at Columbia University. This lack of researchers within MIT department is particularly surprising given the fact that graph theory has emerged in departments across the Institute, and that the Department of Political Science has a strong history of multi-disciplinary collaboration.

Core-Periphery Hierarchy, links occur exclusively within clear-cut cliques in a very rigid and top-down structure. In such a hierarchy, a subservient node may only interact with the node above it. In a *Local Team Hierarchy*, the distributions are further mottled, as nodes of the same team can interact with one another, but must interact with a Hub node. Between the Random Network (typified solely by global interactions) and the Scale-Free Network (typified solely by clique global *and* clique interactions are equally implicit to the network structure. In a Multiscalar Hierarchy, link density (the frequency of links) decreases monotonically with depth. In the top grouping, such hierarchies share a multitude of relationships with one another, with nodes involved in both horizontal and vertical relationships, but by the bottom grouping, relationships are almost entirely vertical. In the image, the darker area implies thicker link density, or *homophily*, between the component nodes. Having already identified that the international system of trade is a Scale-Free Network, we know that the system hierarchy must either be Core-Periphery, Local Team, or Multiscalar. In order to determine which of these hierarchies is in place, we must examine the submacrogroupings of the system.

15.2.3 Exploring Submacrogroupings of the International Trade Network

Scale-Free Networks contain important subsystem groupings which can be used to determine the system's hierarchical structure. A Scale-Free Network has several subsystem groupings, and it is the structure and function of these submacrosystem groupings that have huge ramifications for the international system. If the subsystems are becoming separated and more distinct, as we would expect if regionalism or some other submacroform were on the rise (as Mansfield and Milner, 1999 suggests), we would observe cliques in which the distributions of relationships and the distribution of power increasingly centered on the Hub of the clique. Alternatively, if we were to observe the increasing cohesiveness of nations relative to one another and the emergence of an Egalitarian Network, or a flat world, as Thomas Friedman famously suggests, we would expect to see a transition to a Random Network where cliques and international economies do not matter as much (2005).[25] However, we clearly cannot fully understand the international system or its

[25] Hirst and Thompson discuss the difference between globalization and inter-nationalization, explaining that globalization occurs when a single unified global market is more prevalent than any national markets. Hirst and Thompson explain that the international system is actually one in which inter-national markets dominate the international arena (2002).

macrosystem without understanding the several possible submacrosystems already identified in the international relations literature.[26]

15.2.4 Submacrosystems in International Relations Literature

Submacrosystems come in many forms. Kaplan suggests supranational groupings may make the international order bipolar, or otherwise politically divided (1957); Huntington suggests that the international order is subdivided by cultures (Huntington, 1996); regionalists have explored cooperation among geographically-neighboring states (Schirm, 2002); international political economists frequently investigate trade blocs. In each of these cases, submacrosystems are defined (1) along political or military boundaries, (2) along social boundaries, (3) along geographic boundaries, or (4) along explicitly-defined trade boundaries. This taxonomy of submacrosystems explains all of the types of submacrosystems which form, but no individual gradient of this taxonomy explains all submacrosystems. For instance, if one seeks to capture submacrosystems by classifying countries according to their geographic boundaries or along their cultural (civilization) borders, one will inevitably be forced to neglect other taxonomies or classifications. Cuban international relations from the 1960s to the 1980s were shaped by the Soviet Union, even more so than by their Caribbean submacrosystem counterparts.

Such investigations amount to simplifying at the expense of our understanding of the international system, and such simplifications are common across submacroinvestigations. For instance, one can find research that compares the European Union (EU) and the North American Free Trade Agreement (Abbott, 2000), or research that examines political alliances (Kupchan, 1988), but one is unlikely to find research that compares Asian country relationships to the South African Customs Union, or even research on non-formalized trading communities, where the involved nations cooperate increasingly with one another without the benefits of an official trade alliance. As a result, our understanding of international interactions at the submacrolevel pale in comparison to our understanding of interactions at the micro and macrolevels. In this project, we seek to overcome this condition

[26] The existence of submacroclusters may confirm Huntington's position that subinternational groupings of countries are the best way of conceiving of the macrosystem (Huntington, 1996). Alternatively, the existence of clusters in the international system may confirm those who believe the macrosystem is actually just a set of several regional systems, with the regions primarily dictated by geography (Schirm, 2002). Certainly, there are formal regional structures which countries join, forming explicit clusters. However, in order to determine the true conditions of the system and whether Huntington and the Regionalists are correct, we must identify the latent subsystems.

by observing submacrorelationships embedded within microrelationships.[27] By embedded relationships, we mean patterns that are defined by the behavior: in this case, multilateral patterns emerge from dyadic international trade relationships.

Why consider such embedded relationships at all? In Figure 15.11, a friendship network of children in a US school is shown (Newman, 2003; picture courtesy of James Moody). The light dots represent white children; the dark dots represent black children; the shaded dots represent children of other racial backgrounds. Notice that while children do divide themselves along racial lines, what emerge are four distinct clusters – or communities of children – suggesting that some other divide beyond race exists as well.[28]

As a thought exercise, imagine these dots as countries instead of school children. Each color would then represent exclusive participation in a certain

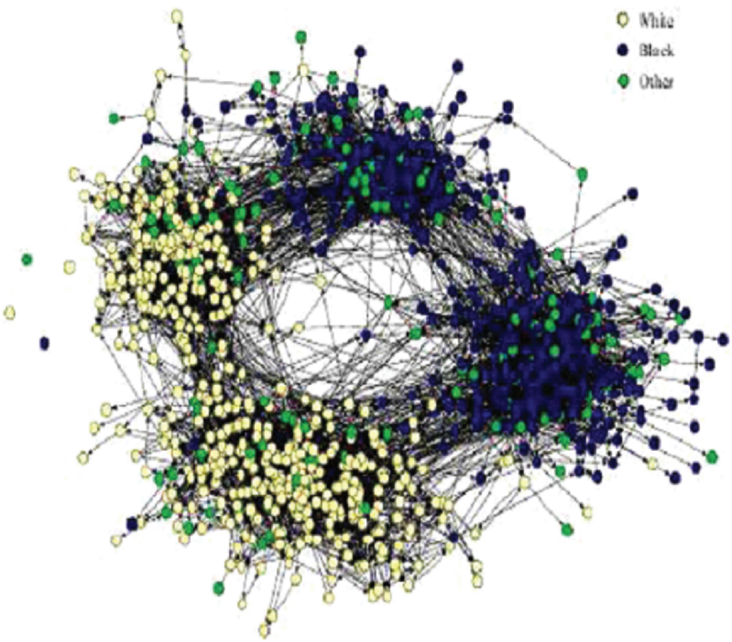

Figure 15.11 **Friendship relationships between children in a US school. Source: Newman, 2003, courtesy of James Moody.**

[27] In earlier drafts of this chapter, we described the latent cliques as "embedded." However, in *The Great Transformation*, Polanyi frequently refers to the economic system being embedded in the interactions of a larger international system, meaning that it is not autonomous. This concept of embeddedness has been adopted by many others, including Granovetter, Ruggie, and Evans (Block, 2001). To avoid confusion, from now on, we will use the term "latent" to describe non-formalized clusters in the international trade system.

[28] One may suspect that this divide is perhaps one of gender or class, but in actuality, it results from an age divide.

explicit trading bloc (such as NAFTA or the EU) as opposed to another trading bloc. However, the common divide within each of the trading groups would not be apparent if participation in a trading group were all that was being considered. Thus, the benefit of identifying each clique in the dataset is that it allows us to observe groupings that are not typically studied. For illustrative purposes, in Figure 15.12 we have provided one such latent submacroclique from 1984. Notice that the seven countries included come from different trade groups, different cultures, different political alliances, and different continents.[29] To be clear, the value of considering latent trade cliques is that they are determined exclusively in terms of trade interactions, without relying upon any prior assumptions about identities or classifications.

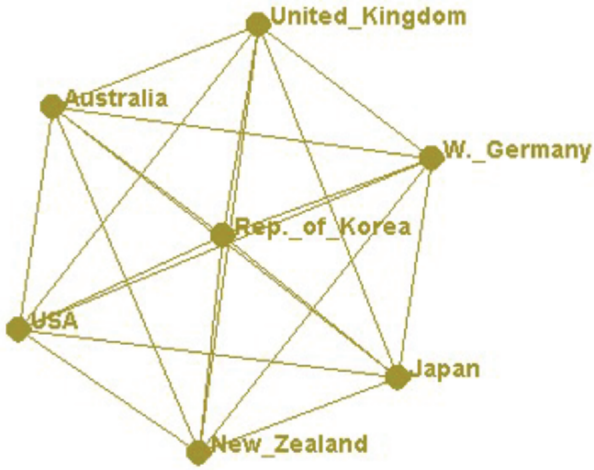

Figure 15.12 **A latent submacroclique in the international system.**

15.2.5 A Submacrograph Theoretic Approach

To identify these several latent submacrogroupings of countries, we shall take full advantages of recent developments in graph theory, especially utilizing advances in *community identification analysis*. Most networks typically have regions where the components are increasingly interconnected relative

[29] A cynic might point out that these countries all belong to the Organization for Economic Co-operation and Development (OECD). However, in 1984, South Korea was not a member of this group and would not join for another 12 years. However, perhaps being so intertwined with these richer countries did help South Korea achieve OECD status, further demonstrating the benefits of examining latent submacrocliques.

to the rest of the network, and these regions are known as *cliques*, or *clusters* (Palla et al., 2005).[30] For our purposes, such *cliques* can be considered as nonformalized submacrogroupings of countries.[31]

Scholars in graph theory have increasingly focused on uncovering latent clique structures within complex networks (Newman, 2004). There are several algorithms that have emerged for identifying these cliques.[32] Among them are *spectral-bisection*, the *Kernighan-Lin Algorithm* (both championed by computer scientists), and the *Bron-Kerbosch Algorithm* (especially useful for finding and defining sociological cliques) (Newman, 2004). In each of these algorithms, the number of latent cliques must be predetermined, and each component must belong to one – and only one – of the cliques. The *Girvan-Newman Algorithm* represents an improvement as it finds "natural" grouping among the components, whereby the user does not have to define how many cliques actually exist at the outset (Newman, 2004).

For studying the international trade system, there are many drawbacks to using any of these algorithms, even the superior *Girvan-Newman Algorithm*. Firstly, by requiring all countries to be classified in a clique, inaccurate groupings of loosely-related nations will be endemic in our analysis. Secondly, by limiting the number of groupings a country may be recognized within to one, these clustering algorithms do not show the full complexity of the international system. Consider the United States, for example, which is heavily involved in trade across the world. If we were to use the *Girvan-Newman Algorithm*, the United States could only be included in one submacrosystem. However, the United States plays an important role in several submacrosystems, interacting in otherwise secluded trading communities in Africa, as well as trading communities in South America, for example. An algorithm which allows us to recognize that a country may belong to more than one clique would be tremendously advantageous.

Palla, Derényi, Farkas, and Vicsek offer a solution in the form of an algorithm which helps the researcher identify components in a network that may belong to several different communities at once (2005).[33] Such an algorithm

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[30] Cliques are also known as clusters, communities, and groupings (Derényi et al., 2005).

[31] By a nonformalized grouping, we mean a grouping that is tied together by the fact that they trade with one another, not *necessarily* by geography, explicit trade bloc status, or culture.

[32] Rather than engage in a lengthy discourse about the mathematics behind each of these algorithms, we shall contain our discussion to the pros and the cons of each algorithm only with regard to our purposes. We recognize that the Palla et al., algorithm which we end up utilizing is the best for our purposes and not necessarily best for other purposes. For a brief introduction to community analysis, consult Newman, 2003 and Newman, 2004.

[33] Palla et al., are all biologists. It is comforting to note that other methodological techniques employed in international relations and biology are also shared. McClelland's concept of equilibrium comes from biology (identified by Goodman, 1965). More recently, evolutionary biologists have adopted methodologies in game theory for their purposes (Hauert and Doebeli, 2004).

provides us a way of identifying latent submacrosystems without limiting the participation of a country to a singular submacrosystem.[34] In Figure 15.13, from Palla et al., the image on the left shows how typical community identification analysis does not recognize overlaps. Such an image is the product of a divisive grouping algorithm, like the four previously identified. The image on the right shows overlapping cliques, with nodes that belong to more than one clique, as produced by Palla et al. Considering the manifest divides in the international system alone, such a structure may be more appropriate: France belongs to NATO and the EU while the United States is a member of both NAFTA and the OECD. The Palla et al., Algorithm offers us the best leverage for considering the submacrosystems of the international trade system.

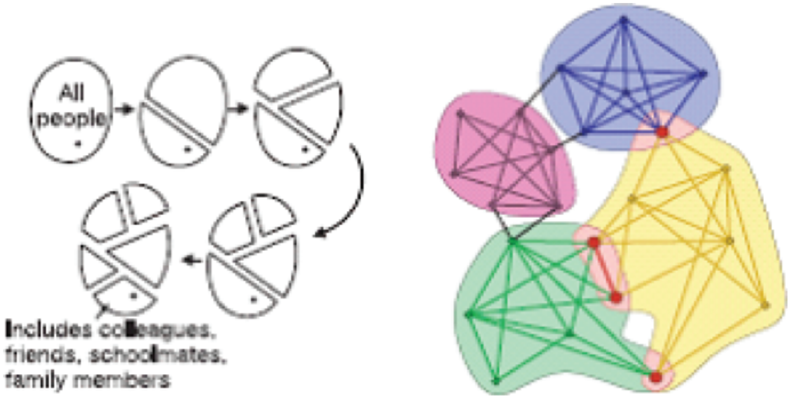

Figure 15.13 **Divisive cliques vs. overlapping cliques. Source: Palla et al., 2005.**

Recognizing that there are overlaps among latent trading communities, the Palla et al. Algorithm allows us to entirely reconsider the submacroconcept. Such community identification analysis should not be confused with typical clustering analysis found in traditional statistics. When one uses methods of clustering analysis found in traditional statistics, one is grouping based upon their relationships with one another rather than basing the observations based upon similar characteristics.[35] Such clustering analysis would be useful for creating a cluster of the richest countries in the world, for example. In contrast, community identification analysis group countries upon their similar attributes. In order not to further confuse the reader, we shall not use the term “cluster” to describe our submacrogroupings, but instead we shall call them either

[34] The algorithm was originally constructed to observe protein cliques in yeast to make predictions for the unknown functions of some proteins (Derényi et al. 2005).

[35] Newman observes that the algorithms used for clustering analysis and community identification analysis are similar, but distinct (2003).

cliques or communities, both acceptable substitutes in the graph theory literature (Newman, 2004; Palla et al., 2005).

The Palla et al. Algorithm is based upon an adaptation of an existing method for identifying latent cliques.[36] The existing method is known as the Clique Percolation Method (CPM). The CPM identifies cliques by scanning for *k*-cliques. A *k*-clique is one in which all nodes within the clique share a specified minimum number of edges minus one. More formally, *k*-cliques are "complete (fully connected) subgraphs of *k* vertices" (Derényi, Palla, and Vicsek, 2005: 160202-2). In Figure 15.14, a *k*-clique is presented where $k = 2$. Because it is the minimum number of edges, notice that despite the fact that two of the nodes in this figure actually have four edges, the rest of the nodes have three edges, making $k = 2$. Essentially, a CPM algorithm scans the data for each of these *k*-cliques starting at $k = 3$, then proceeding to $k = 4$, and so on. As a result, any clique requires at least 3 nodes. As the algorithm reaches the maximum *k*-clique, the percolation method instructs the algorithm to terminate.

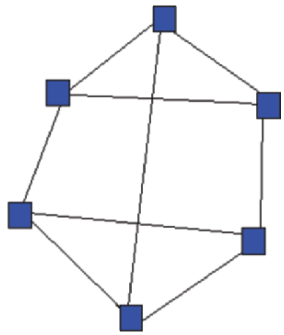

Figure 15.14 **A *k*-clique where *k* = 2.**

Ordinarily, once a typical algorithm identifies a node at one *k*-clique level, it does not group that node with any other clique at that level. The Palla et al. Algorithm differs from the previous algorithms in that a node may still be included in another clique. In other words, nodes are included across several cliques, even at a common *k*-clique level (Derényi et al., 2005; Palla et al., 2005). Palla et al., have graciously made their clique-identifying algorithm publicly available and free of charge, even providing a graphical user interface for convenience (2005).[37] The program which they create, known as CFinder, visually displays the latent cliques.

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[36] For those further interested in the mathematics behind the algorithms, first consult the Derényi et al., article in *Physical Review Letters*, 2005, before Palla et al., 2005, in *Nature*.

[37] For Palla et al.'s algorithm and clustering program, visit http://angel.elte.hu/clustering/ (accessed April 2006).

To locate and identify the submacrostructures, we again use export data from the UN Comtrade Database from 1962 to 2003. From this data we again identify dyadic relationships between countries, again only including major trade relationships.[38] Once the data is organized in terms of dyads, stored in a text file, and selected, we can run the calculations and compute the latent clusters using CFinder. CFinder not only allows us to identify relationships and display latent clusters, but it also provides graphs the clusters. However, CFinder does not incorporate spring embedding or any energy minimization function into its graphs, of making some of the visualizations very difficult to analyze without the help of Netdraw or Pajek.

15.2.6 Examining Submacrosystems to Identify the Macrosystem

Looking at the macrosystem, we ruled out the possibility of a Random or a Random Interdivisional Hierarchy existing across the entire network, as we found that the macrosystem is actually a Scale-Free Network. However, Random Hierarchies and Random Interdivisional Hierarchies do exist at the submacrolevel, as do Core-Periphery Hierarchies and Local Team Hierarchies. Networks can have a variety of hierarchies, and when a network has multiple hierarchies, it enters the Multiscalar region.

One should not simply accept the statement that all hierarchies are prevalent in the international trade system, however, as we have the means of demonstrating it. In order to determine the nature of the macrosystem, we have to examine the several international submacrosystems. Three types of cliques emerge from our analysis, displaying a range of *interdependence*. Rosencrance and Stein identify at least three different ways in which interdependence has been previously conceived in international relations:

> In its most general sense, interdependence suggests a relationship of interests such that if one nation's position changes, other states will be affected by that change. A second meaning, derived from economics, suggests that interdependence is present when there is an increased national "sensitivity" to external economic developments … The most stringent definition comes from Kenneth Waltz, who argues that interdependence entails a relationship that would be costly to break (Rosencrance and Stein, 1973: 2).

We adopt the most general notion of the term, that if one nation changes itself, other states will be affected by that change.[39] The amount that a nation will be affected by another nation depends upon the form of interdependence.

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[38] Major trade relationships are already defined and explained in the preceding sections.

[39] In reading the literature, we were struck by the number of authors who would discuss interdependence without defining the term.

In terms of latent cliques, interdependence ranges from cliques with one Hub and several Spokes to cliques with multiple Hubs and several Spokes to cliques with several countries of the same hierarchical type. In each case, if one nation changes itself, other states will be *differently* affected by that change.

15.2.6.1 Pure-Dependent Submacrosystems

The first clique formation we shall label a *Pure-Dependent Submacrosystem*. In this clique, a Hub country is crucial to tying the flow of international trade to the rest of the clique and therefore, these Spoke countries are solely dependent upon the Hub. Take, for example, a $k = 4$ latent clique from 2002, as shown in Figure 15.15. The other countries in the latent clique are functionally dependent upon the United States to connect to the larger trade network. Excluding the United States, the average clustering coefficient of the group is 0.6786, much higher than the United States' 0.4190 coefficient, with a low clustering coefficient suggesting diversity of partners, and in turn, increased interconnectivity with the international system.[40] As a result, power is heavily concentrated with the United States and if Hirschman is correct, we would expect to see the United States able to coerce these other countries if necessary, both economically and politically (1980).

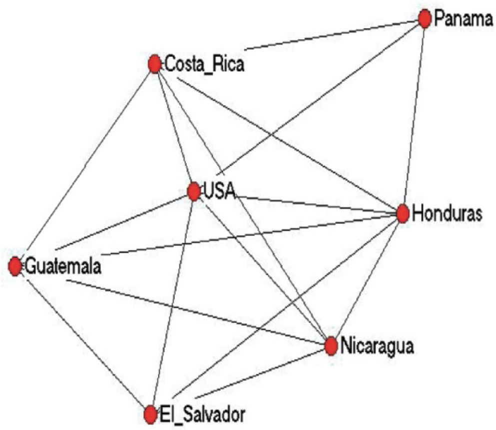

Figure 15.15 **A *k* = 4 latent clique from 2002 (countries labeled).**

[40] The clustering coefficient for a node is the likelihood that its partner nodes interact with one another. In terms of trade, imagine three countries: A, B, and C. If countries A and B trade, and countries B and C trade, the clustering coefficient shows the likelihood of a trade relationship existing between countries A and C.

Hirschman empirically demonstrates that large trading countries have a preference to interact with smaller trading countries (1980). Hirschman explains that given two countries, a strong one (Country A), and a weak one (Country B), Country A has an interest in monopolizing the trade of Country B, and Country B has an interest in "splitting its trade equally among as many countries as possible in order to escape too great a dependence on one or two great markets or supply sources" (Hirschman, 1980: 85–86). The logic for such a struggle is simple: trade dependencies give the dominant country the ability to affect the weak country, both in terms of economic coercion as well as social and political coercion. In addition to statistical analysis, Hirschman also offers a convincing case study in Nazi Germany. Hirschman observes that the Nazis used trade relations to first penetrate, and then dominate countries in several areas, especially in Southeast Europe.

Hirschman's work is focused upon dyadic relationships, but his theories can be extrapolated for the rest of the international system, offering other interesting insights. For instance, having a large trade deficit is not as detrimental for a Hub if other countries are becoming increasingly dependent upon that country, particularly if that Hub is a Hegemon. The Hub is gaining relatively to the other countries in the system, making it more integral to the stability of the system. If that country collapses, other countries which are dependent upon the Hub country are equally in trouble. This property is similar, but not identical, between the various hierarchical structures we identified earlier.[41] However, this Pure-Dependent clique formation most closely conforms to a Random Interdivisional Hierarchy, but it may also occur within a larger Local Team, Core-Periphery, or Multiscalar Hierarchy.

15.2.6.2 Identifying Gatekeepers

When a Random-Interdivisional Hierarchy or a Multiscalar Hierarchy is in place, a certain country may prove crucial to tying the horizontal flow of trade between two cliques. We define such countries as *Gatekeepers*, as they have the ability to regulate interactions between the submacrogroupings. In Figures 15.16 and 15.17, we see that a clique of primarily European countries and a clique of primarily Asian countries are principally connected through just a few Gatekeepers.

Gatekeepers can influence other nations by their positions not just in the macrosystem, but also by their positions between cliques. Gatekeepers need not only be Hub countries as we observed Pakistan serving as one of many Gatekeepers in 1982. In the 1980s, aid flows to Afghanistan from the Soviets and the West made Afghanistan play a Gatekeeper role in the international

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[41] We speculate that this property depends upon the vertical nature of the hierarchy, and we plan on examining this property at another time.

aid system. Such a role as the intermediary helped Afghanistan avoid capitulating to Soviet coercion as the Western clique fought to protect its sovereignty during the Soviet invasion of the 1980s.

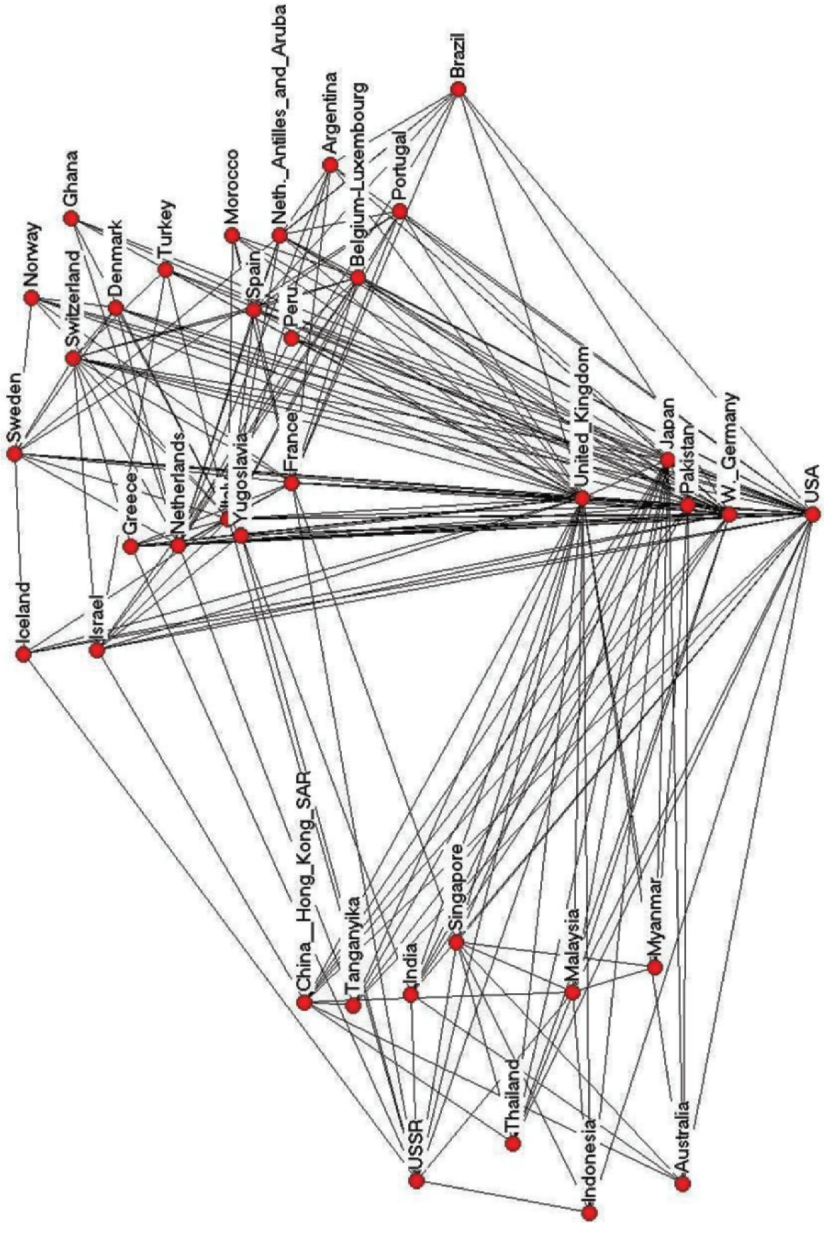

Figure 15.16 **Two *k* = 6 cliques and their connecting nodes (countries labeled).**

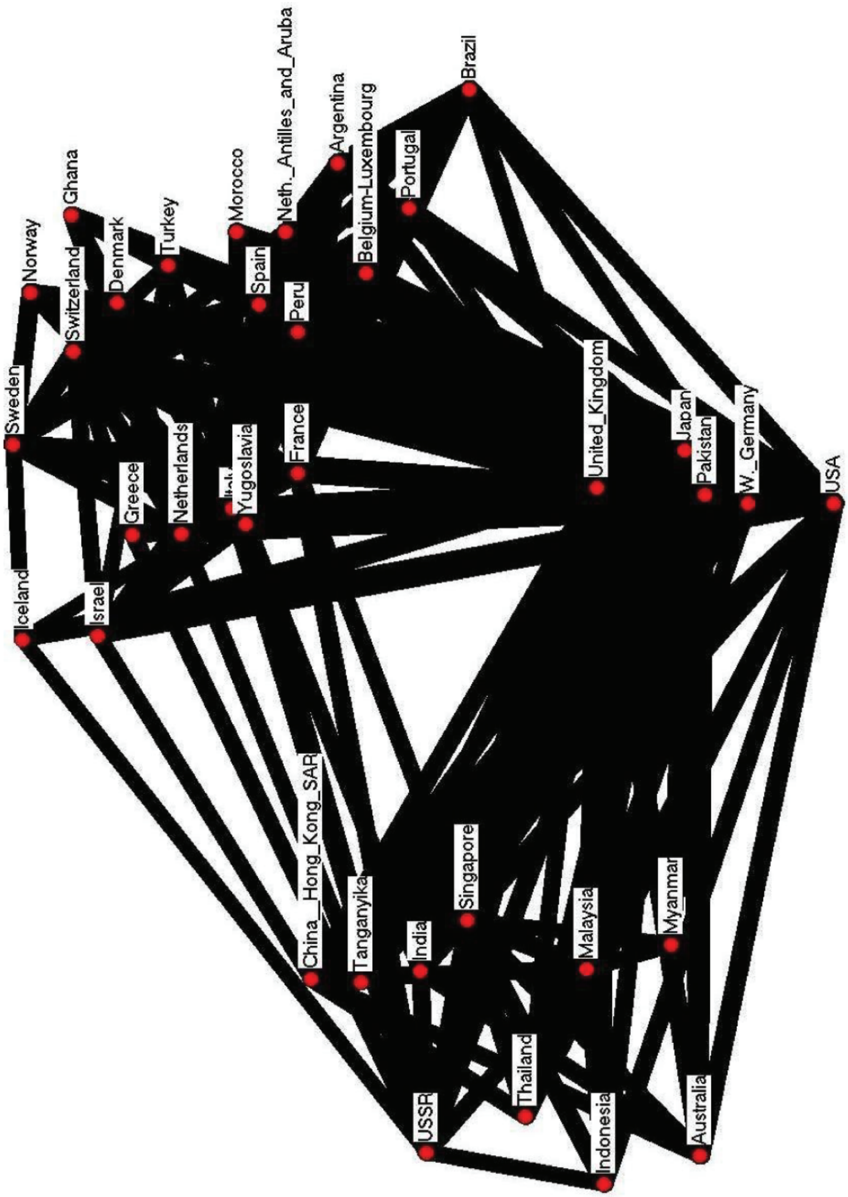

Figure 15.17 **Two *k* = 6 cliques and their connecting nodes, with weighted relationships (countries labeled). Notice that most of the trade flows through the bottom right group of countries.**

Further applying Hirschman's logic to submacrosystem dynamics, dominant countries not only have an incentive to minimize other Gatekeepers, but they should strive to become Gatekeepers themselves. If a country can fully control a submacrosystem and serve as the submacrosystem's only link between those Spokes and the rest of the international order, that Hub country will rise in relative and absolute power. For the United States, such was the logic of the Monroe Doctrine of the 1800s. Discovering those isolated cliques in order to connect them with the larger world trade system also drives trade expansionism today in much the same way as colonialism and mercantilism influenced country policies over the last 500 years.

Hubs would have an interest in breaking down other Hubs' monopoly power, or at the minimum, Hubs would want to see trade relationships develop among a rival country's Spokes and the international system. For example, it is beneficial to the Europeans that Japan, China, and South Korea are increasingly competing against one another while vying for better positions in the macrosystem, so long as one of these countries does not emerge on top and so long as these countries do not join forces in some supernational structure. If China emerges as the dominant country in East Asian trading circles, with subordinates of the caliber of Japan and South Korea, China would instantly enjoy greater position in the trade system.

15.2.6.3 Multi-Dependent Submacrosystem

Not surprisingly, we do find cliques with multiple Hubs. In these cliques, Spoke countries are not completely dependent upon a sole Hub and connect to the international system through an alternate route. As a result, if one Hub introduces a form of coercion on the Spoke, the Spoke has the ability to resist by turning to the other Hub, tempering the coercive ability of the original Hub. Within such a submacroclique, there is a system in effect, whereby each Spoke has a level of autonomy from its multiple Hub partners, and thus we classify such clique relationships as a *Multi-Dependent Submacrosystem*.

One such clique, a $k = 5$ clique from 1984 is presented in Figure 15.18. Notice how West Germany and the United States, each with high clustering coefficients and significant trade participation across the world, share the markets of Costa Rica, Guatemala and El Salvador. In such a condition, the Spoke countries are stronger because if one Hub country engages in coercion, the Spoke countries may turn to the other Hub country for assistance. However, compared to the Gatekeeper relationship, if one Hub country cannot push the other Hub country out of the submacrosystem, the two Hub countries are likely to increasingly cooperate, forming an oligopoly (Hirschman, 1980).

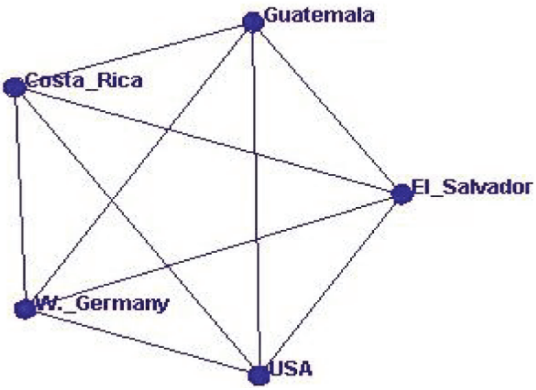

Figure 15.18 **A *k* = 5 latent clique from 1984 (countries labeled).**

15.2.6.4 Mutually-Dependent Submacrocliques

Rounding out the range of submacrocliques are latent cliques that are made up of countries which are mutually dependent upon one another. Most of the high value *k*-cliques are such communities, and they are usually solely comprised of Hub countries. The latent clique presented in Figure 15.19 is one such clique. This clique formation is an *Mutually-Dependent Submacrosystem*, whereby the resilience of the system is highly contingent upon each of the members of the community. These upper-level cliques are the closest approximations of Egalitarian Networks observed in the international trade system.

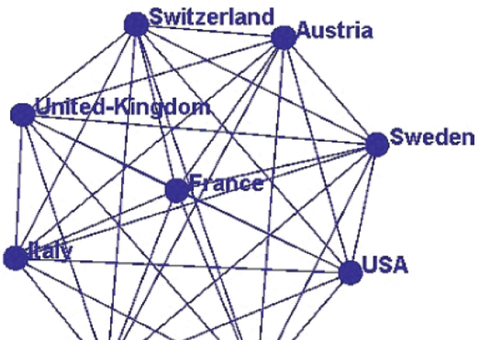

Figure 15.19. **A *k* = 9 latent clique from 1964 (countries labeled).**

In terms of hierarchical possibilities, such a clique displays high *homophily*, or high interconnection between its members. This clique is necessary for a Scale-Free Network, and it is necessary for Multiscalar, Local Team, and Core-Periphery Hierarchies. Such a small and exclusive latent clique would not be found in the Random or Random Interdivisional Hierarchies as it would not occur in a purely Random Network.[42]

Combined, this evidence suggests that a Multiscalar Hierarchy exists, as we do see elements of Random Interdivisional and Random Hierarchies, as well as elements of Core-Periphery and Local Team Hierarchies. Just as we would expect in a Multiscalar Hierarchy, we do observe some level of homophily, or horizontal trade, but we also observe a significant amount of vertical trade as well. As one moves vertically up the hierarchy, higher and higher levels of homophily are present.

15.3 Re-Examining the Macrosystem in the Context of the Submacrosystem

We shall now put the components together. Both our macro and submacroanalysis suggest that the macrosystem is governed by a network of Hubs heavily interacting with one another. Typically, the Hubs are European or Western, but in recent times, other countries such as India and China have joined the higher levels of trade. In Figure 15.20, we display the theoretical structure of the upper echelon, as justified by our macro and submacrolevel analyses. It is not surprising that such a structure resembles what we would expect in a Balance of Power System, with several Hubs of approximately equal trade capabilities.

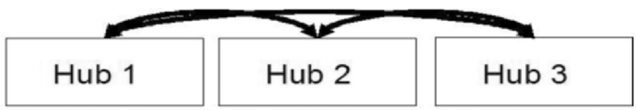

Figure 15.20 **The theoretical upper-echelon.**

In Figures 15.21 and 15.22, we present two theoretical double-level, Multiscalar hierarchies distinct from those of Dodds et al. In Figure 15.21, we offer an international system with only Pure-Dependent Submacrorelationships in the vertical frame. In Figure 15.22, we depict an international system laden with Multi-Dependent Relationships. The edge thickness in each figure represents the homophily: notice that the edges between the Hubs are thicker than the edges between the Hubs and Spokes.

[42] A clique like this one may occur in an Egalitarian Network if the population was limited to only these countries.

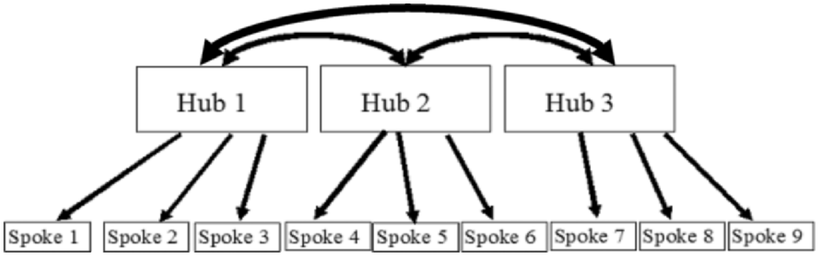

Figure 15.21 **The upper-echelon with spokes connected through Pure-Dependent Submacrorelationships.**

Also, in the real-world hierarchy, there are many levels, with intermediary components connecting countries in a far more complex pattern than what is presented below. We posit that the hierarchic international system of trade lies somewhere in between these two structures, with the modern-day trend approaching Figure 15.22 as the degrees of separation between nations reduces. We suspect this transition because in our analysis, we do see a drop in the average degree of separation, and in the real-world we do hear of greater involvement by Hubs in these so-called *emerging markets*.

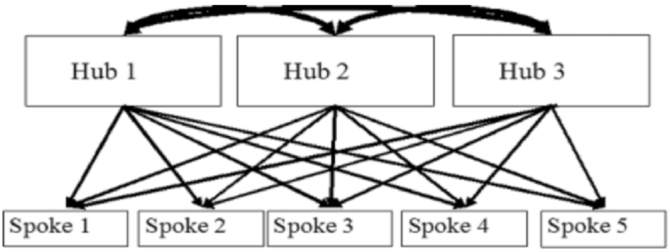

Figure 15.22 **The upper-echelon with spokes connected through Multi-Dependent Submacrorelationships.**

Reconsidering cascading failures, in either structure such contagion effects should tend to spread either horizontally or descend through the system. Additionally, due to the high homophily in the upper echelons of the trade hierarchy, the upper echelon members should be more or less resilient when faced with bottom-up disturbances, relative to the amount and depth of interconnections between the Hubs and the Spokes. In other words, if the economy of a small country collapses, we would not expect any large economies to collapse unless several other small country economies collapsed at once. However, if the economy of a large country collapses, we would expect the small country to suffer as well.

15.4 Conclusion

Graph theory is useful for understanding a system's overall structure, but it is also useful for understanding relative positions of elements within a system. In this chapter, we have utilized graph theory to explain stability and contagion, both of which are important aspects of sustainability. We find that the international system is predisposed towards horizontal and top-down contagion, but that it is remarkably resilient to contagion effects that rise from the bottom-up. In other words, the economic collapse of a small country is unlikely to adversely affect any large economy. We also find that certain countries in the international system have a greater ability to exercise coercion, not just from their absolute elements (such as military force or economy size), but also due to their relative elements (consider major power monopolization).

In this chapter, we have just scratched the surface of the possibilities of graph theory for better understanding conditions for sustainability of trade patterns. Similar to the system of international trade, many issues of sustainability are under girded by complex patterns of interactions between various stakeholders. Understanding these patterns can yield beneficial results across many domains. Furthermore, graph theory is still developing and growing as a field. As our understanding of the systems involved in sustainability develops, and as graph theory is developed, we expect to see new and exciting directions for research in sustainability due to graph theory. Graph theory can help us better understand these patterns and can help us craft better policies for the future.

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