Introduction

One distinct trend over the last decade in international trade is a growing regionalism. That is, there has been a proliferation of regional trading alliances, such as the North American Free Trade Agreement (NAFTA), the European Union, Mercosur customs union etc. In fact, currently there are over a 100 of such agreements in the world (Ethier, 1998). At the same time, numerous multilateral and bilateral alliances have been formed between nations of different regions. Given these developments, one might argue that what is evolving in the international trading network is a "small-world" network, one in which there is a high degree of regional connectivity, or cliquishness and strong global connectivity. When one factors in actual trading activity, or economic exchanges between nations, it is unclear as to whether or not a "small-world" network actually exists. It is possible that the trading alliances that exist are to some degree ineffective, suggesting a lack of global and regional connectivity. In other words, a "small-world" network may not in fact be present.

This paper introduces two methods, one based on shift-share analysis and the other on ANOVA, that can be used to measure the evolution or devolution of "small-world" connectivity in a network. While both models produce essentially the same information, the ANOVA approach provides a statistical grounding to the shift-share analysis. Both methods produce global, regional and local effects for each node in the network of interest. In the case of trade networks, the focus of this paper, the nodes are nations. Weights on the nodes are measured in terms of exports. The global effect for a nation is an indicator of how changes in exports for that country have been influenced by what has been occurring at the international level. The regional effect is similar, however it indicates how changes in a nation's exports have been influenced by changes within the region it is located. The local effect is in essence a residual factor, providing information on the extent to which local factors have contributed to the growth or decline of exports from a nation. In this paper, the shift-share model is applied to a select set of nations for three time periods: 1985-1990, 1990-1995, 1995-2000.

In the next section, the concept of "small-world" connectivity is discussed. The third section describes how a "small-world" network topology in terms of a graph has evolved in the case of international trade. Network topology is defined based on regional trading alliances and agreements, as well as bilateral and multilateral arrangements across regions. In the fourth section, the shift-share and ANOVA models are introduced and discussed in the context of trade networks. Section five applies the shift-share model and presents the findings of this analysis. Conclusions are drawn in section six.

Small-World Network Connectivity

"Small-world" network connectivity is a new concept that has been receiving a lot of attention. Introduced by Watts and Strogatz (1998), a "small-world" network is based on "six degrees of separation," or the notion that everyone in the world is related to everyone else by at most six acquaintances. "Six degrees of separation" stems from the formation of cliques and a few popular individuals that provide connections between cliques. "Small-world" are similar in that they have a high degree of local clustering or cliquishness, like a regular lattice and a relatively short average minimum path, like a completely random network. Unlike "six degrees of separation" though they do not assume random connectivity. Rather, "small-world" networks lie somewhere in between a regular lattice and a random network. Watts and Strogatz (1998) assert that this phenomenon is probably universal, applying to many natural and manmade networks. They cite the United States power grid, the neural network of a particular type of worm, and the network of actors and actresses as examples of "small-world networks."

"Small-world" networks are characterized by their average path length L(p) and the degree to which there is local connectivity in the network, measured by a clustering coefficient C(p). The variable L(p) measures the average minimum path in the network and C(p) the connectivity of an average neighborhood in the network. More specifically, L(p) is the smallest number of links it takes to connect one node to another, averaged over the entire network, and clustering is the fraction of adjacent nodes connected to one another. One may view L(p) as a global property of the network and C(p) a local property.

Watts and Strogatz (1998) show that a "small-world" network lies somewhere in between a regular lattice and random network. To demonstrate this, they begin with a regular lattice with n vertices and k edges, and rewire it in such a way that it approaches a random network. Specifically, beginning with a vertex, the edge connected to its nearest neighbor is reconnected with probability p to another vertex chosen randomly from the rest of the lattice. No rewiring occurs if there already exists a connection to that vertex. This process continues by moving clockwise around the lattice, and randomly rewiring each edge with probability p, until the lap is completed. Next, the same process is repeated for vertices and their second nearest neighbors. Because they consider a network with only first-order and second-order connections in each direction of the vertex, the rewiring process terminates after two laps.

In general, for a network with k nearest neighbors, rewiring will stop after k/2 laps. As the network is rewired, shortcuts through the network are created, resulting in an immediate drop in L(p). Local clustering, or C(p), remains relatively high up to a point after which it begins to drop rapidly. This results of this process suggest that the global connectivity of a regular network can significantly improve with the addition of just a few shortcuts. And in essence, a "small world" network is one with high degree of local clustering and a short average minimum path.

The huge appeal of "small-world networks" lies in the impact they are said to have on dynamical systems. According to Watts and Strogatz (1998), for example, "models of dynamical systems with small-world coupling display enhanced signal propagation speed, computational power, and synchronizability." Furthermore, contagious diseases tend to spread more freely in "small-world networks." These findings have profound implications for many manmade and natural systems. In a telecommunications network, for example, "small-world" network connectivity may improve the ease with which information diffuse through the system.

Trade Networks and "Small-World" Connectivity

In terms of international trade, "small-world" topology appears to be evolving. Over the last several years, there has been a dramatic increase in the number of regional trading alliances. In other words, cliquishness has risen, or in terms of "small-world" network topology, C(p) has strengthened. At the same time, a number of multilateral and bilateral agreements between nations of different regions have been formed, in essence creating "short-cuts" or connections between cliques, contributing to a lower L(p).

The trend toward regionalism or in “small-world” network terminology, the formation of regional cliques began several years ago. The Association of Southwest Asian Nations (ASEAN), for example, was founded in 1967 by the nations of Indonesia, Malaysia, the Philippines, Singapore and Thailand. Brunei Darussalam later joined in 1984, Vietnam in 1995 and Burman and Laos in 1997. The original purpose of the organization was to enhance regional cohesion through cooperative arrangements. The ASEAN Declaration states that the aims of the organization are to “(1) accelerate the economic growth, social progress and cultural development in the region through joint endeavors in the spirit of equality and partnership in order to strengthen the foundation for a prosperous and peaceful community of Southwest Asian nations, and to (2) promote regional peace and stability through abiding respect for justice and the rule of law in the relationship among countries in the region and adherance to the principles of the United Nations Charter” (http:\www.asean.or.id).

In the late 1980’s and 1990’s, some of the regional trading alliances that formed prior to that time strengthen and in addition a number of new alliances were formed. The Andean Group was re-energized in 1991 with the ratification of the Act of Barahona. This agreement was designed to promote the development of a free trade zone and the establishment of a common tariff with four levels (from 5% to 20%). Columbia, Ecuador, and Venezuala have since then formed a free trade zone and have implemented a common external tariff (CET) along with Bolivia. Peru also increased its participation in the group, but only on a transitional and modest basis.

ASEAN also recruited new members during this time period. Vietnam joined in 1995 and agreed to reduce it's tariffs by 0-5% by 2006. Further, the Philippines agreed to make a concerted effort to liberalize its trade policy with other ASEAN nations. Member nations agreed in 1992 to nearly eliminate intra-ASEAN trade tariffs on most goods by 2007, thereby establishing an ASEAN free trade area.

In 1989, the United States and Canada entered into a free trade agreement, which called for an elimination of bilateral tariffs on trade by 1998. The North America Free Trade Agreement (NAFTA), ratified in 1993, extended this agreement to Mexico and expanded the scope of the earlier free trade agreement.

During the 1990's a number of bilateral and multilateral agreements were formed between nations of different regions, providing connections between cliques. In 1991, for example, the Andean Trade Preference Act (APTA) was established. This agreement reduced the cost of trading between South American countries and the United States by eliminating duties on certain exports going to the United States. In 1997, Canada and Chile entered into a Free Trade agreement. Some of the provisions of the arrangement include duty-free access for a large share of Canadian exports and the elimination of Chile's import duty on a range of goods. Negotiations to include Chile in the North American Free Trade Agreement began in 1995.

In 1994, Mexico signed a free trade agreement with Columbia and Venezuala. This was one of the most liberal trade agreements in Latin America, offering price advantages over United States goods and services for member nations. Mexico and Chile also signed an agreement during the 1990's. In 1994, Chile entered into a free trade agreement with Ecuador. By 1995, tariffs on most goods trade between Chile and

Ecuador were eliminated. All tariffs were to be reduced completely by 2000. Over the last decade, Ecuador has made an effort to abandon the protectionist trade policy it had in the eighties with a more liberal trading regime. Chile also formed a free trade agreement with Columbia in the same year with the intent of reducing import duties over a five-year period.

While "small-world" topology appears to have evolved in the network of trading nations of the world, there is still a question of what impact this topology is having on the actual economic interaction between nations in terms of trade. If in fact, a "small-world" network exists, then one would expect to see nations within regions being affected by each other's trading and at the same time they would be connected to the global market through dominant players within their region. For example, in a "small-world" network a regional agreement like NAFTA would not only enhance economic interaction between the United States, Mexico and Canada, but it would assist the latter two nations in becoming more connected to the rest of the world vis-à-vis the United States. In the next section, a set of methods are introduced that can be used to test this hypothesis and to gauge the extent a "small-world" network has evolved in terms of actual economic interaction between nations.

What makes these techniques unique are that they allow one to examine "small-world" connectivity in networks with weighted links and nodes. Most of the work that has been done on "small-world" networks to date focus on graphs, or networks with unweighted nodes and links. There are a few attempts to move beyond this but they are still quite preliminary (Yook et. al., 2001).

Measuring "Small-World" Connectivity

In this section, we introduce two methods that can be used to measure the evolution of "small-world" connectivity in networks with weighted nodes and links. These techniques include a "modified" shift-share model and a hierarchical ANOVA model. In essence, both methods produce the same information, yet the ANOVA approach provides a statistical backing to the shift-share model. Both models generate for some specified time interval (e.g., five year time period), three different effects for each nation: global, regional and local. The global effect for a nation measures the extent to which changes in its exports have been influenced by changes in exports at the international level. The regional effect is similar, however it measures how a nation's change in exports can be explained by trends in exporting within the region it is located in. The local effect is in essence a residual factor, providing information on the extent to which local factors have contributed to the growth of exports from a nation.

These effects are captured using a modified "shift-share" model. "Shift-share" analysis is typically utilized to measure the degree to which changes in employment, sales or income in a region are affected by three factors: national growth, industry mix and competitive share. The national growth component indicates by how much industrial growth in a region is affected by activity at the national level, or some super regional level. The second factor captures the effect that the industrial mix of the region has on economic activity. Lastly, the competitive share component measures the effect of local factors that may be enhancing or hindering economic growth in the region.

In the case of trading networks, the following shift-share model is formulated. The global effect is expressed as follows:

$$G_i = Exp_{it}*g \qquad (1)$$

where, Exp_{it} are exports from nation i at time t and g is the mean rate of change in exports for the world. The regional effect takes the following form:

$$R_i = Exp_{it}*(g_r - g) \qquad (2)$$

where g_r is the mean rate of change in exports for region r. Lastly, the local effect is formulated as follows:

$$L_i = Exp_{it}*(g_i - g_r) \qquad (3)$$

where g_i is the rate of change in exports for nation i.

The modified shift-share model is analogous in some sense to a nested fixed effects ANOVA model. For three levels—e.g, global, regional and national, the model takes the following form:

$$X_{ij} = \mu + \alpha_i + \beta_{ij} \qquad (4)$$

Where, X_{ij} is the rate of change in export activity for nation j in region i, μ the grand mean change for the world or the effect global trading activity, α_i the effect of the region in which it is located and β_{ij} a residual effect. The only difference between the nested fixed effects ANOVA and the shift-share model is that the former lacks exports as a factor and instead it focuses exclusively on changes in activity. Nonetheless, the two models produce similar pieces of information, and again the ANOVA connection provides some statistical grounding to the shift-share model.

Application of the Shift-Share Model

In this section, the shift-share model previously introduced is used to assess whether or not a "small-world" network is evolving in the international trade network. The model is applied to three distinct time periods: 1985-1990, 1990-1995, and 1995-2000. Merchandise exports in millions are used as a measure of connectivity. Data was collected from www.worldbank.org.

The countries included in the analysis are summarized in Table 1, along with their regional grouping. Regions are defined based on physical proximity but also by regional trading alliances and agreements. For example, North America includes the United States, Mexico and Canada, all members of the North American Free Trade Agreement. By defining regions in this manner it is then possible to test whether or not the "small-world" topology that exists because of these agreements actually contribute to the development of a "small-world" network once trading activity is considered or in network terminology once weights are added to the nodes.

The findings of the model are mixed in terms of whether or not a "small-world" network exists in international trade. If one exists, each nation in the model should have both positive values for global and regional effects, which would indicate a high degree of local clustering and strong global connectivity in the network. These factors correspond to C(p) and L(p) in "small-world" network topology.

Table 1: Regional Groupings for the Shift-Share Analysis

NORTH AMERICA	**LATIN AMERICA**	**WESTERN EUROPE**	**AFRICA**	**EASTERN EUROPE**
United States	Argentina	Austria	Algeria	Bulgaria
Mexico	Bahamas	Denmark	Angola	Hungary
Canada	Brazil	Finland	Cameroon	Poland
	Chile	France	Congo,Dem. Rep. Of	Romania
MIDDLE EAST	Colombia	Germany	Ivory Coast	
Bahrain	Costa Rica	Greece	Egypt	**ASIA**
Iran	Cuba	Ireland	Gabon	Australia
Israel	Dominican Republic	Italy	Ghana	Brunei Darussalam
Kuwait	Ecuador	Netherlands	Kenya	China
Oman	Guatemala	Norway	Libya	Hong Kong
Qatar	Netherlands Antilles	Portugal	Morocco	India
Saudi Arabia	Peru	Spain	Namibia	Indonesia
Syria	Trinidad/ Tobago	Sweden	Nigeria	Japan
UnitedArab Emirates	Uruguay	Switzerland	South Africa	Korea, Rep. Of
	Venezuela	Turkey	Tunisia	Malaysia
		United Kingdom	Zambia	New Zealand
			Zimbabwe	Pakistan
				PapuaNew Guinea
				Singapore
				Sri Lanka
				Taiwan
				Thailand

One result that is consistent is that all nations for each of the three time periods do have positive global effects, with the magnitude of these factors increasing over time for many nations. This finding is logical given that advancements in technology and transportation appear to be bringing the world closer together but it may also imply that bilateral and multilateral agreements between different regions are contributing to greater trade between them.

The findings are not so consistent for the regional effects. Some groupings, like the United States, Mexico and Canada, have become more connected suggesting that the NAFTA agreement may be strengthening the economic relationship between the three participating countries. This is further substantiated by the fact that the regional effects for Canada, the United States and Mexico were all negative prior to NAFTA.

Europe provides an interesting case. Prior to 1990, all nations in Europe had positive regional effects, however following the formation of the Europe Union these effects turned negative. The nations of Europe all still remain highly connected to the rest of the world though. All other nations in the world have consistently had negative regional effects suggesting perhaps that the regional trade alliances they are involved in have been ineffective in terms of promoting regional economic interaction. Negative regional effects are shown for all three time periods for all of the nations of Africa, Latin America, Asia and the Middle East.

There is some evidence of "small-world" connectivity. Correlation coefficients between each combination of effects for all three time periods were computed. They are shown in Table 2. At least for the first two time periods, the correlation between global and regional connectivity is positive and moderately strong. This suggests that in order for a nation to be globally connected it needs to be regionally linked, and in particular linked to a nation that is a major player in the international trading arena.

Table 2: Correlation Coefficients Between Global, Regional and Local Effects

	1985-1990	1990-1995	1995-2000
Global& Regional	0.688	0.661	-0.218
Regional& Local	-0.642	-0.477	-0.138
Global &Local	-0.395	-0.819	-0.755

If one looks at the top 20 nations in terms of positive global effects for each of the three time periods, each region has at least one nation that is highly connected to the rest of the world economically. Table 3 provides a summary of these countries. In "small-world" network terminology this are the countries that provide linkages between regions, or cliques, creating short-cuts through the network and enhancing overall global connectivity.

Table 3: Top Ten Nations With Positive Global Effects

1985-1990	1990-1995	1995-2000
United State Germany	Germany United States	United States Germany
Japan	Japan	Japan
France	France	France
United Kingdom	United Kingdom	United Kingdom
Canada	Italy	Italy
Italy	Netherlands	Canada
Netherlands	Canada	Netherlands
Taipei, Chinese	Hong Kong, China	Hong Kong, China
Sweden	Taipei, Chinese	China
Korea, Rep. of	Korea, Rep. Of	Korea, Rep. of
Hong Kong, China	Switzerland	Singapore
Saudi Arabia	China	Spain
Switzerland	Sweden	Taipei, Chinese
China	Spain	Switzerland
Mexico	Singapore	Mexico
Brazil	Saudi Arabia	Malaysia
Spain	Austria	Austria
Singapore	Mexico	Sweden
Australia	Australia	Thailand

Conclusions

This paper introduces a set of methods for assessing "small-world" connectivity in any network with weighted nodes and links. Most research done on "small-worlds" to date focus exclusively on graphs (i.e., non-weighted nodes and links). Using the shift-share model presented, "small-world" connectivity in the international trade network is examined. The findings are mixed. All nations have become more globally connected over the last 15 years, however many have not become regionally linked despite regional alliances and agreements. The effectiveness of these arrangements should be further explored – e.g., to what extent has LAFTA really contributed to economic cohesion and interaction in Latin America.

References

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