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Economic Analysis of Free Trade Agreements: Spaghetti Bowl Effect and a Paradox of Hub and Spoke Network

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Abstract

This paper shows a new exposition of the Trade Diversion Effect when Free Trade Agreements are created. Hub and spoke type of trade networks cause systemic overproduction, and member countries exit from the markets, whereas perfectly connected networks create sustainable markets in any number of markets. Since there are two basic patterns for creating FTAs, bilateral and multilateral, a network pattern is derived from these negotiation patterns. The hub country may be aggressive in pursuing Free Trade Agreements with various countries, but accumulation of bilateral negotiations may cause Trade Diversion Effect in the regional economies.

- **JEL classification:** F13, F17, L13
- **Keywords:** Free Trade Agreements, Network Theory, Graph Theory, Trade Diversion Effect, Spaghetti Bowl Effect

I. Introduction

Proliferation of FTAs is underway. This paper shows that the type of FTA negotiated is of overwhelming importance to achieve equilibrium between trading countries in regionally integrated markets. In most of the existing literature on Free Trade Agreements (FTA) or regional trade integration, economic models ignore the

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patterns of connections among foreign markets. One can recognize, however, the existence of two basic patterns of Free Trade Agreement (FTA). One is bilateral agreements accumulated by a certain country. The other is multilateral agreements between several countries. The differences between bilateral and multilateral agreements generate different network patterns.

Bilateral trade talks are being pursued by countries such as Japan, Korea and China. Japan, for example, made a bilateral FTA with Singapore in 2002[1], with Mexico in 2004[2], and hopes to resume talks with Thailand. In 2005 Japan also negotiated Economic Partnership Agreements with Korea, Philippines and Malaysia.

On the other hand, NAFTA is a typical example of a multilateral agreement. One can see that the United States, Canada and Mexico conduct multilateral talks, and NAFTA creates a triangular network of trade. The EU is another example of a multilateral agreement, and the EU benefits its participants in the form of multilateral negotiations.

Singapore and Thailand are members of the ASEAN Free Trade Area (AFTA) and they enhance their free trade areas to include Japan. Mexico is a member of NAFTA but it aggressively negotiates trade agreements with Japan, EU and other countries.

In the classic exposition of Viner(1950), two countries and "the rest of the world" are taken as an example, and later expositions such as Lipsey(1960) and Yotopoulos and Nugent(1976) followed suit. Bilateral agreements were considered as the simplest case of a multilateral FTA. Recent inquiry, such as Gatsios and Karp(1991) presupposes game theoretic interactions between member countries. In their framework, however, they also use two countries and "the rest of the world" as the structure of a trade model.

Krugman (1991) shows the results of a simulation based upon his assumptions about world trade. He concluded that the welfare level is highest when B=1, where B is the number of trade blocks. This is the state of free trade throughout the world. When the world is divided into three trade blocks, i.e., B=3, the welfare level

[1]"The Agreement between Japan and the Republic of Singapore for a New-Age Economic Partner-ship" (JSEPA) came into force on 30 November 2002. Low (2003) and Horaguchi (2002) describe how Singapore acts as a member country of ASEAN Free Trade Area.

[2]"Agreement between Japan and the United Mexican States for the Strengthening of the Economic Partnership" was signed on 17 September 2004.

becomes the lowest. Krugman (1991) argues that this result of his simulation gives a theoretical basis for concern that the world's recent tripolarization into North America, Europe, and Asia may have the effect of shrinking trade.

Yi (1996) supposes a welfare function of quadratic form for identical countries, and discusses the case where some of the countries form a regional association. He draws a conclusion that Nash equilibrium is attained when the whole world is integrated into a single regional association, i.e., world free trade gives the highest welfare to every country. The logic suggests that "open regionalism" will increase public welfare, bearing APEC in mind. Baldwin (1989) draws the conclusion that the dynamic effect of scale economies makes the growth rate shift upward, bearing the EU integrated market in mind. Ballard and Cheoug(1997) estimate the effect of tariff reductions in Asian countries using a Computational General Equilibrium model.

One of the major contributions on multilateral agreements is found in Bagwell and Staiger(1997), which deals with multilateral tariff cooperation during the formation of free trade areas. Rivera-Batiz and Romer(1991) discuss the merits of regional integration by endogenous growth theory. One can say that endogenous growth theory enables economic modeling to show the benefit of regional integration without assuming a classic Ricardian trade theory of comparative advantage. According to Ricardian trade theory, two nations with completely identical production functions and factor price endowments cannot obtain trade profits by specializing in "garments" or "wine" as in Ricardo's illustration. Endogenous growth theory captures the reality that the rate of changing technical stock and therefore of technical progress is an increasing function of human resources. As long as regional integration facilitates the accumulation of human resources in a production location, the rate of technical growth will also be accelerated.

All of these models assume that markets are connected as a multilateral network. This implies that existing literature does not explicitly deal with patterns of market connections. The NAFTA triangle, for example, can be captured by a graph. ASEAN Free Trade Area (AFTA) is another example of multilateral negotiations as Tan (1996) depicts its process. Multilateral talks are considered as a perfect network in Graph Theory.

Bilateral talks by Japan and Singapore and consequent talks such as Japan-Thailand, Japan-Mexico, and Japan-Philippines create a hub and spoke type markets connection, which is different from a perfectly connected graph. This paper applies Graph Theory to consider the implications of different structures of market connections. Network theory also contributes to consider the structure of market connections since it consists of a class of Graph Theory.

With the aid of graph theory, one can investigate the efficiency and equilibrium of connected markets. It may be assumed that creation of FTAs would be efficient no matter how they are connected, or it may be naïvely believed that hub and spoke type networking may also be efficient in market economies. This assumption persists in reasoning that the effectiveness of hub and spoke type network reduces the number of connections. The ratio between the number of connections in perfect connection and in hub and spoke type connection is n(n-1)/2 to (n-1). Hendricks, Piccione, and Tan(1995) showed a hub of size n-1 can be an optimal network for the airline industry. However, this paper shows that the hub and spoke type of network creates disequilibrium in certain cases, or nonexistence of equilibrium, whereas a perfectly connected network creates sustainable markets in any number of markets.

The recent surge in the use of graph theory in economic models assumes networks among firms, but not networking of markets. Jackson and Wolinsky (1996) and Jackson and Watts(2002) show companies operating under the framework of economic networks. Kawamata(2004) showed Cournot competition where four firms are graphically connected to reduce variable costs. Since these models assume networking among companies operating in a single market, international trade is not considered. In economic theory or in policy discussions to create FTAs, the negotiation type is clearly important. Yet the implications of structural differences between multilateral and bilateral talks are not taken into account in the existing literature in Economics, nor in policy implementation.

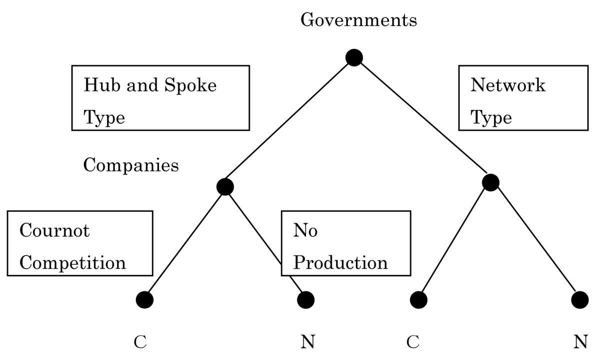
In Section 2, I explain the basic model of graphically connected markets with Cournot competition. Section 3 explicates the model using the terminology of rigorous Graph Theory. Section 4 shows the most striking case of five markets where the inverse matrix disappears and also shows that spoke countries reach zero production levels when hub and spoke networks exceed more than six member countries. In Section 5, I discuss how market connections could evolve, given a hub and spoke network of five markets. In these examples, I show consequences of FTAs to induce “Spaghetti Bowl Effect” (Bhagwati, 2002) in the world economy. The final section draws some conclusions and implications for regional integration.

II. Basic Model

I assume a two stage game with four governments as shown in Figure 1. I also assume that there exists only one company in one market, and each company produces a single product which is not discreminatory by customers. The examples of this class of products are wheat, powdered sugar, edible oil, beef cattle, copper wire, low-grade tires, and synthetic resin, all of which are not differentiated by corporate brands.

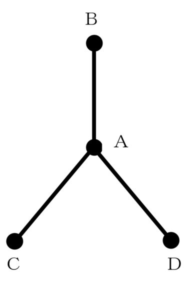
In the first stage, governments decide the type of market connections. This is the stage of creating free trade agreements. The second stage follows this FTA agreement. If two markets are connected by reducing trade barriers, then Cournot competition is simply observed as duopolistic competition between two markets. Since duopolistic competition occurs for a non-differentiated good, two companies

Figure 1. Two Stage Game of Governments' Negotiation and Companies' Competition



Source: Author.

Figure 2. Hub and Spoke Network for Four Markets



Source: Author

in the connected markets react with the same reaction function for the good. In other words, a company A, which produces in country A for country B, supplies the same amount of good as company B, which produces in country B for Country A. In short, a symmetrical reaction function is assumed for the connected market.

If more than two markets are connected to one another, then more entrants compete within the connected market by FTAs. Like Murphy, Sherali, and Soyster(1982), Sherali and Leleno(1988), and Kolstad and Mathiesen(1991), I assume the following conditions for each firm in these markets. The cost function of a company *i*, $C_i(x_i)$, with production volume x_i. The cost function is assumed to be differentiable and it is assumed $C_i'(x_i) = d_i = d$. In other words, the variable cost is assumed to be the same for each firm *i*. Then each firm *i* maximizes the profit function $\pi^i(x^i)$ with respect to x^i. Given that an FTA is interpreted as a Graph which has one of various different possible patterns of connections, let us take one specific example, which becomes a leading case for the following discussions. Figure 2 is the case where three countries are connected by a single hub country.

In this graphically connected market, there exist four distinct markets, A, B, C, and D. These markets are connected as a hub and spoke type. Let the market A be a hub, then there is Cournot competition between four companies in market A. Therefore the demand curve in market A is written as

$$a - bx^A = a - b(x_A^A + x_B^A + x_C^A + x_D^A)$$

and likewise,

$$a - bx^B = a - b(x_A^B + x_B^B)$$

in market B. Thus, in market A, firm A maximizes the following profit function with respect to x_A^A to compete against firms operating in market A. The firm A maximizes its profit function with respect to competing firms against market j.

$$\pi^A(x^A) = (a - b(x_A^A + x_B^A + x_C^A + x_D^A))x_A^A - C_A(x_A^A + x_A^B + x_A^C + x_A^D)$$

$$\text{Subject to } x_A^j \geq 0, x_B^j \geq 0, x_C^j \geq 0, x_D^j \geq 0.$$

In market A and B, firm B maximizes

$$\pi^{B}(x_{b}^{B}) = (a - b(x_{A}^{B} + x_{B}^{B})) - C_{B}(x_{B}^{A} + x_{B}^{B})$$

Subject to $x_{A}^{j} \geq 0, x_{B}^{j} \geq 0.$

In the case of firm C and D, the identical profit maximization is assumed.

$$\pi^{C}(x_{c}) = (a - b(x_{A}^{C} + x_{C}^{C}))x_{C}^{C} - C_{C}(x_{C}^{A} + x_{C}^{C})$$

Subject to $x_{A}^{j} \geq 0, x_{C}^{j} \geq 0.$

$$\pi^{D}(x_{D}) = (a - b(x_{A}^{D} + x_{D}^{D}))x_{D}^{D} - C_{D}(x_{C}^{A} + x_{D}^{D})$$

Subject to $x_{A}^{j} \geq 0, x_{D}^{j} \geq 0.$

The first order conditions $(\partial\pi^{i}/\partial x_{i})$ for graphically connected markets can then be expressed as a system of equations:

$$a - b(2x_{A}^{A} + x_{B}^{A} + x_{C}^{A} + x_{D}^{A}) - d_{A} = 0$$

$$a - b(x_{A}^{B} + 2x_{B}^{B}) - d_{B} = 0$$

$$a - b(x_{A}^{C} + 2x_{C}^{C}) - d_{C} = 0$$

$$a - b(x_{A}^{D} + 2x_{D}^{D}) - d_{D} = 0$$

Since I assumed symmetry in the competition $x_{j}^{i} = x_{i}^{j}$, and the same variable cost of $C_{i}^{'}(x_{i}) = d_{i} = d$, one can rewrite the above equations as:

$$\begin{bmatrix} q_a \\ q_b \\ q_c \\ q_d \end{bmatrix} = \begin{bmatrix} 2 & 1 & 1 & 1 \\ 1 & 2 & 0 & 0 \\ 1 & 0 & 2 & 0 \\ 1 & 0 & 0 & 2 \end{bmatrix} \begin{bmatrix} x_a \\ x_b \\ x_c \\ x_d \end{bmatrix} \tag{1}$$

where $q_{i} = (a - d)/b,\ (i = a, b, c, d)$. The inverse matrix is calculated and the equation is rewritten as:

$$\begin{bmatrix} 2 & -1 & -1 & -1 \\ -1 & 1 & 0.5 & 0.5 \\ -1 & 0.5 & 1 & 0.5 \\ -1 & 0.5 & 0.5 & 1 \end{bmatrix} \begin{bmatrix} q_a \\ q_b \\ q_c \\ q_d \end{bmatrix} = I \begin{bmatrix} x_a \\ x_b \\ x_c \\ x_d \end{bmatrix} \tag{2}$$

Then, equilibrium quantities of the industry are derived as the following:

$$\begin{bmatrix} x_a \\ x_b \\ x_c \\ x_d \end{bmatrix} = \begin{bmatrix} (-a-2d_a+d_b+d_c+d_d)/b \\ (2a+2d_a-2d_b-d_c-d_d)/b \\ (2a+2d_a-d_b-2d_c-d_d)/b \\ (2a+2d_a-d_b-d_c-2d_d)/b \end{bmatrix} \tag{3}$$

In order to consider the properties of this equilibrium, let us consider the case where $d_i = d_j (i,j = a, b, c, d)\ (i \neq j)$. Then,

$$\begin{bmatrix} x_a \\ x_b \\ x_c \\ x_d \end{bmatrix} = \begin{bmatrix} (-a+d)/b \\ (2a-2d)/b \\ (2a-2d)/b \\ (2a-2d)/b \end{bmatrix} \tag{4}$$

If $a>d$, then $x_a<0$. Given the constraint of non-negative production level, straightforward maximization does not lead to an optimum of the system. Firm A results in zero production level since there is a non-negative constraint for x_a. Firm A might produce non-negative production in autarchy, but bilateral agreements with three countries result in zero production level.

In order to check the above mentioned properties of excess production in these graphically connected markets, let us assume a simple set of parameters. If the parameter $q_i = (a-b_i)/b,\ (i = a, b, c, d)$, is normalized to unity (q_i=1, i=a,b,c,d) then we get the following result for the quantities produced by each firm.

$$\begin{bmatrix} 2 & -1 & -1 & -1 \\ -1 & 1 & 0.5 & 0.5 \\ -1 & 0.5 & 1 & 0.5 \\ -1 & 0.5 & 0.5 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} x_a \\ x_b \\ x_c \\ x_d \end{bmatrix} = \begin{bmatrix} -1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \tag{4a}$$

If the total production of this graphically connected market is 2, then the markets as a whole can attain profit maximization of the firms. Firm A in country A, however, cannot produce a negative amount of 1. This is a corner solution to the system of these markets. So firm A must cease to exist. The rest of the firms, from three countries B, C, and D can produce the amount of 1, but they still suffer over production from the total production level of 3. The three countries may either reduce the production level by one third, or one of the three countries may stop its production. One can assume that the three countries are producing a total amount of three, but the assumption is naïve as long as profit maximization is not attained. The three companies may suffer losses, due to price reduction in the total market.

In this market connection of the hub and spoke markets as a whole, the system suffers excess production. Furthermore, even if firm A attains zero production level, the entire system still suffers over production for each of the member countries of the FTA.

Proposition 1: In a graphically connected market of the hub and spoke type among four countries, the hub country suffers negative production to sustain the equilibrium, given identical demand conditions and production parameters. Thus, firm A can no longer exist as an incumbent.

The four by four matrix in equation (1) shows how the network is created. Given the Cournot competition model above, connection of the markets can be mapped into this adjacency matrix. The first row and the first column are occupied by one, and then diagonal cells are filled by two. This pattern persists in any number of markets as long as they are connected like hub and spoke. I would like to check whether other types of market connections can save Firm A to attain a positive production level. The triangle plus one shape has its matrix in the system,

$$\begin{bmatrix} q_a \\ q_b \\ q_c \\ q_d \end{bmatrix} = \begin{bmatrix} 2 & 1 & 1 & 1 \\ 1 & 2 & 0 & 0 \\ 1 & 0 & 2 & 1 \\ 1 & 0 & 1 & 2 \end{bmatrix} \begin{bmatrix} x_a \\ x_b \\ x_c \\ x_d \end{bmatrix} \tag{5}$$

So the inverse matrix and equilibrium production level is expressed by;

$$\begin{bmatrix} 1.2 & -0.6 & -0.4 & -0.4 \\ 1 & 0.8 & 0.2 & 0.2 \\ 1 & 0.2 & 0.8 & -0.2 \\ 1 & 0.2 & -0.2 & 0.8 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} x_a \\ x_b \\ x_c \\ x_d \end{bmatrix} = \begin{bmatrix} -0.2 \\ 0.6 \\ 0.4 \\ 0.4 \end{bmatrix} \tag{6}$$

Firm A's output is still negative and the total production is 1.2. We next check perfect network of four markets. The perfectly connected markets have the following system of equations:

$$\begin{bmatrix} q_a \\ q_b \\ q_c \\ q_d \end{bmatrix} = \begin{bmatrix} 2 & 1 & 1 & 1 \\ 1 & 2 & 1 & 1 \\ 1 & 1 & 2 & 1 \\ 1 & 1 & 1 & 2 \end{bmatrix} \begin{bmatrix} x_a \\ x_b \\ x_c \\ x_d \end{bmatrix} \tag{7}$$

$$\begin{bmatrix} 0.8 & -0.2 & -0.2 & -0.2 \\ -0.2 & 0.8 & -0.2 & -0.2 \\ -0.2 & -0.2 & 0.8 & -0.2 \\ -0.2 & -0.2 & -0.2 & 0.8 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} x_a \\ x_b \\ x_c \\ x_d \end{bmatrix} = \begin{bmatrix} 0.2 \\ 0.2 \\ 0.2 \\ 0.2 \end{bmatrix} \tag{8}$$

This is equivalent to textbook type Cournot competition. The total production of this system of perfectly connected markets is 0.8. The lowest among the three meaningful types of connected markets mentioned above. However, all of the incumbents in the system are able to have positive production levels.

Proposition 2: Perfectly connected markets allow all firms to produce non-negative level of production.

III. General Exposition by Graph Theory

We can now sum up the result of the basic model using terminology of Graph Theory[3]. Let the elements of a set $X = \{1,,, n\}$ represent firms. It is firms which are the decision makers and thus objectives of analysis, given networking of markets among nations as created by Free Trade Agreements. Established competition, or international trade between any two firms of X are denoted by an *undirected* graph $G(V;E)$, where: V is the set of vertices, $V = \{v_1,v_2,,, v_n\};$ a one-to-one mapping of the set of firms X onto itself (the graph is labeled), and $n = |V|$ is the number of vertices (nodes), also known as the *order* of the graph. E is a proper subset of the collection of unordered pairs of vertices, $q = |E|$ is the number of edges, and is also

[3]Yannis(2004) was particularly useful to understand various kinds of economic models with Graph Theory.

known as the *size* of the graph. We say that firm i interacts with another firm j if there is an edge between nodes i and j, *or two firms i and j.* Let v(i) define the local neighborhood of firm i : $v(i) = \{j \in X / i \neq j, \{ij\} \in E\}$. The number of i's neighbors is the *degree* of node i : $d_i = |v(i)|$.

Graph $G(V;E)$ is represented equivalently by its adjacency matrix, Y, an $I \times I$ matrix whose (i,j) element, Y_{ij} , is equal to 1, if there exists an edge connecting agents i and j; and to 0, otherwise. In the particular class of Graph in the case of Cournot competition, (i,i) elements of adjacency matrix Y have value of 2 since the first order conditions of the profit function reflect the square of x_i in the profit functions in each market of i. Recalling that entry into foreign markets occurs simultaneously, we consider here undirected graphs. Matrix Y is symmetric and positive, and we can get the inverse matrix of Y, now denoted as Θ, which is also symmetric. Θ allows, however, negative elements.

IV. Hub and Spokes in Five Markets

It is interesting to investigate the behavior of the hub and spoke type of graphically connected markets. As a possible extension of the four markets case, let me consider the case of five markets having hub and spoke connections. The first order condition of maximiz ation gives the system of:

$$\begin{bmatrix} q_a \\ q_b \\ q_c \\ q_d \\ q_e \end{bmatrix} = \begin{bmatrix} 2 & 1 & 1 & 1 & 1 \\ 1 & 2 & 0 & 0 & 0 \\ 1 & 0 & 2 & 0 & 0 \\ 1 & 0 & 0 & 2 & 0 \\ 1 & 0 & 0 & 0 & 2 \end{bmatrix} \begin{bmatrix} x_a \\ x_b \\ x_c \\ x_d \\ x_e \end{bmatrix} \tag{9}$$

Subject to; $x_i \geq 0, i = a, b, c, d, e.$

It was somewhat surprising to see that the above system does not have an inverse matrix. The hub and spoke type with five markets is not sustainable at an equilibrium production level[4].

Proposition 3: There exists no inverse matrix for the hub and spoke, five markets network of equation (9) under identical market conditions of Cournot competition.

[4]If one can change the parameter of this model, there exists an inverse matrix.

Appendix 1 gives proof of proposition 3. One can further calculate various numbers of markets with hub and spokes type. Table 1 shows the production level of firm x_a, comparing the results with the perfectly connected markets case. The perfectly connected case is nothing but Cournot competition in a textbook exposition. It is somewhat breathtaking that naïve belief in the efficiency of hub and spoke type of network is not sustained when more than four markets are connected[5].

When the number of markets exceeds six, all of the spoke countries suffer negative production level under the entire system. Since nonnegative constraints bind, the spoke countries have to stop production. Nonnegative constraints for the production level induce corner solutions with null production levels of certain countries. This is a new exposition of the Trade Diversion Effect. This theory suggests that the connection patterns cause trade diversion from some member countries.

Proposition 4. For more than 6 markets, which are connected as hub and spokes, spoke countries incur zero production level.

Proof of the proposition 4 is also given in Appendix 1.

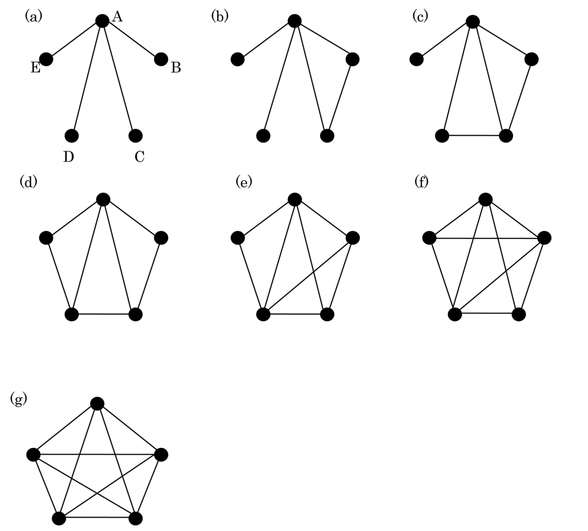
Tabel 1. Number of Markets and Production Levels of the Firm

	Perfectly Connected		Hub and Spoke Type of Markets	
	x_a	$x_i \neq a$	x_a	$x_i \neq a$
2	0.333	0.333	0.333	0.333
3	0.250	0.250	0	0.5
4	0.20	0.20	-1	1
5	0.166	0.166	no inverse matrix	
6	0.142	0.142	3	-1
7	0.125	0.125	2	-0.5
8	0.111	0.111	1.66	-0.333
9	0.1	0.1	1.5	-0.25
10	0.090909	0.090909	1.4	-0.2
25	0.038462	0.038462	1.1	-0.05

Source: author.

[5]One can easily guess that if the country A could have a larger market size, the system may allow a different production level for Firm A.

Figure 3. Hub and Spoke Type of Market Connection and Added Connections



Source: author.

V. Creation of Networks from the Hub and Spoke Type of Connection

Although the inverse matrix does not exist for the five markets, hub and spoke type network with identical demand and supply conditions, one can see that positive production levels are resumed when network is created. Figure 3-(a) is the hub and spoke type of networking, where one can see the burden of country A is larger than other spoke countries.

From this hub-and-spoke-type Figure 3-(a), one can add connections one by one[6]. There are five types of connections from Figure 3-(b) to 3-(e) to be a perfect network of Figure 3-(g). The results of equilibrium production of seven types are summarized in Table 2. There is only one case in which all firms attain positive production level. The perfectly connected network, Figure 3-(g), is the only system with positive production levels for all firms.

[6]It is needless to say that five nodes can create a wider variety of graphs. I focused here on the evolution of markets' connections from hub and spoke type of market connection.

Table 2. Levels of Production in Five Country Graph Connections

Graph Type	Country					
	A	B	C	D	E	Total
(a)			no inverse matrix			
(b)	-2	1	1	1.5	1.5	3
(c)	-1	1	-0.14	1	1	2.99
(d)	-0.25	0.5	0.25	0.25	0.5	1.25
(e)	-0.25	0.5	0.5	-0.25	0.75	1.25
(f)	0	-0.56×10^{-16}	0.5	-0.11×10^{-15}	0.5	0.99
(g)	0.166	0.166	0.166	0.166	0.166	0.833

Source: author.

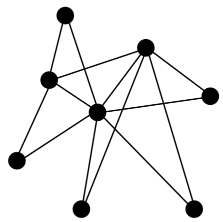
Proposition 5: A graph of perfectly connected markets is the only graph which attains positive production level for all firms in five markets, from which is evolved over hub and spoke types of connection.

Proposition 5 is proved by checking all of the possible cases, which are summarized in Table 2.

VI. Some Cases from Network Theory

Barabasi and Albert (1999) introduce another way to create a network. It is called a Scale-Free Network and is created by two rules. The first rule is that for each given period of time one node is added to a network. The second rule is that each new node is connected to existing nodes with two links, for which the probability of connection to another node is higher the greater the number of links to that node. An Example is given in Figure 4 in which Barabasi (2002, p87)

Figure 4. Scale-Free Network with Eight Nodes



Source: Barabasi (2002, p87)

introduces a case of eight nodes.

This market connection has two properties. One is that this network retains some characteristics of hub and spoke networks. That is, one market is acting as a hub market for the other spoke markets. The other property in this example is that the hub market has more than six connections, which assures a non-negative production level for the hub market. The adjacency matrix of Figure 5 is given by equation (10).

$$\begin{bmatrix} 2 & 1 & 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 2 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 2 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 2 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 2 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 2 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 & 2 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 2 \end{bmatrix} \tag{10}$$

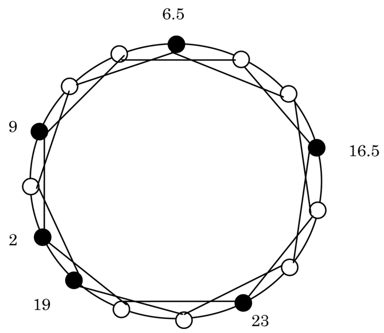
Calculating the inverse matrix, we get total production of 6.08^{31}(or, 6.08E+31 in a software language). Three nodes record 2.03^{31}, one node records 3.66^{15}, and two nodes have 2.25^{15}. Two nodes attain minus production levels, so the non-negative constraint binds to get zero production level. As compared to the perfect network, or the other types of network considered in this paper, the Scale-Free Network with eight nodes shows a highest level of production. Thus, a variety of Scale-Free Networks should be studied further in relation to the “Spaghetti Bowl Effect” of Free Trade Agreements.

The greater the number of markets, the more types of network connections there are. The properties of specific types of Graphs can only be followed by simulation results as long as those Graphs are considered in the context of networked markets. Here, we consider one specific case of fifteen markets.

Fifteen markets in a circular market model show stable production level in Figure 5. This circular market model of fifteen markets has production level of 76. On the other hand, perfectly connected markets with fifteen markets attain an equilibrium of 0.9375(0.0625 multiplied by 15), whereas hub and spoke markets have total output of 1.2.

The total production level was sought by simulation, given different types of fifteen-market networks. A tree type, a wheel type, two hub-and-spoke types which

Figure 5. Fifteen Markets with Total Output of 76



Note: Black nodes produce non-negative output, whereas white nodes are bided by non-negative constraint to show zero production level.

are connected by a single "axon," and double wheel type are simulated to study their production levels. Among those trials the connections of Figure 5 showed high production level of 76. This type of network is inspired by "Small World Network" [Watts (2003)], but a connection between two markets (nodes) in the circle significantly reduced the production level.

Figure 5 shows that the highest production level is attained by the seventh market, which showed production level of 23. This result is striking because it leads to doubts on the existence of externalities in market transactions. If several markets are connected evenly to neighboring markets, some of the markets emerge with extremely high production levels. This high production level may be inferred as a result of externality in markets.

The conditions of each market are the same *ex ante*, but some lucky markets grow to produce huge volume *ex post*. This is nothing but a kind of invisible hand to create uneven development of economic locations. Deterministic historical explanations are not able to show sufficient conditions for the emergence of focal market in Figure 5. *Invisible Selection* of certain locations is dependent on the shape of market networks, or an adjacency matrix and its inverse matrix. In that case, externality, supply and demand, factor proportions, and corporate rivalry are not relevant to explain the emergence of a market with high production volume.

VII. Conclusion

This paper shows a new exposition of the Trade Diversion Effect when bilateral

Free Trade Agreements are accumulated with a single hub country. The hub and spoke type of networking causes systemic overproduction and member countries need to exit from the markets. The hub country may be aggressive to pursue Free Trade Agreements, but the consequence is to cause Trade Diversion Effects to spoke countries. This consequence should not be underestimated. On the other hand, perfectly connected markets induce increasing production levels and lowering price.

There are two regimes of FTAs. One is to pursue multilateral negotiations. EU is a typical example of this. The other, such as Japan, is to pursue bilateral negotiations. Setting aside advocacy of global free trade, discussion on the "Spaghetti Bowl Effect"(Bhagwati, 2002) in this paper shows a possibility to worsen trade balances with Trade Diversion Effects. Accumulation of bilateral negotiations may cause a systemic turmoil in the regional economies. The importance of multilateral negotiations must be reassessed with the eyes of rigorous exposition in economics.

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Appendix 1. Proof of Proposition 3 and 4.

The hub and spoke type of market networks with n-countries has an adjacency matrix of the following type.

$$n\left\{\begin{matrix} \overbrace{\begin{matrix} 2 & 1 & 1 & 1 & . & 1 \end{matrix}}^{n} \\ \begin{matrix} 1 & 2 & 0 & 0 & . & 0 \\ 1 & 0 & 2 & 0 & . & 0 \\ 1 & 0 & 0 & 2 & . & 0 \\ & . & . & . & . & . \\ 1 & 0 & 0 & 0 & . & 2 \end{matrix} \end{matrix}\right. \tag{A1}$$

The diagonal cells are filled by 2, and the first row and the first column are filled by 1 except the upper left corner. Let us apply Gauss-Jordan Elimination to get the inverse matrix of (A1).

$$n\left\{\begin{matrix} \overbrace{\begin{matrix} 2 & 1 & 1 & 1 & . & 1 \end{matrix}}^{n} \\ \begin{matrix} 1 & 2 & 0 & 0 & . & 0 \\ 1 & 0 & 2 & 0 & . & 0 \\ 1 & 0 & 0 & 2 & . & 0 \\ & . & . & . & . & . \\ 1 & 0 & 0 & 0 & . & 2 \end{matrix} \end{matrix}\right. \quad n\left\{\begin{matrix} \overbrace{\begin{matrix} 1 & 0 & 0 & 0 & . & 0 \end{matrix}}^{n} \\ \begin{matrix} 0 & 1 & 0 & 0 & . & 0 \\ 0 & 0 & 1 & 0 & . & 0 \\ 0 & 0 & 0 & 1 & . & 0 \\ & . & . & . & . & . \\ 0 & 0 & 0 & 0 & . & 1 \end{matrix} \end{matrix}\right.$$

The first row is multiplied by -2, and each of other rows is added to the first row, then;

$$n\left\{\begin{matrix} \overbrace{\begin{matrix} -4+(n-1) & 0 & 0 & 0 & . & 0 \end{matrix}}^{n} \\ \begin{matrix} 1 & 2 & 0 & 0 & . & 0 \\ 1 & 0 & 2 & 0 & . & 0 \\ 1 & 0 & 0 & 2 & . & 0 \\ & . & . & . & . & . \\ 1 & 0 & 0 & 0 & . & 2 \end{matrix} \end{matrix}\right. \quad n\left\{\begin{matrix} \overbrace{\begin{matrix} -2 & 1 & 1 & 1 & . & 1 \end{matrix}}^{n} \\ \begin{matrix} 0 & 1 & 0 & 0 & . & 0 \\ 0 & 0 & 1 & 0 & . & 0 \\ 0 & 0 & 0 & 1 & . & 0 \\ & . & . & . & . & . \\ 0 & 0 & 0 & 0 & . & 1 \end{matrix} \end{matrix}\right.$$

The first row is divided by -4+(n-1)=n-5, to have;

$$n\left\{\begin{array}{cccccc} \multicolumn{6}{c}{\overbrace{\qquad\qquad\qquad}^{n}} \\ 1 & 0 & 0 & 0 & . & 0 \\ 1 & 2 & 0 & 0 & . & 0 \\ 1 & 0 & 2 & 0 & . & 0 \\ 1 & 0 & 0 & 2 & . & 0 \\ . & . & . & . & . & . \\ 1 & 0 & 0 & 0 & . & 2 \end{array}\right. \quad n\left\{\begin{array}{cccccc} \multicolumn{6}{c}{\overbrace{\qquad\qquad\qquad\qquad\qquad\qquad}^{n}} \\ -2/(n-5) & 1/(n-5) & 1/(n-5) & 1/(n-5) & . & 1/(n-5) \\ 0 & 1 & 0 & 0 & . & 0 \\ 0 & 0 & 1 & 0 & . & 0 \\ 0 & 0 & 0 & 1 & . & 0 \\ & . & . & . & . & . \\ 0 & 0 & 0 & 0 & . & 1 \end{array}\right.$$

Each of the rows below the second is subtracted by the first row to eliminate 1s in the first column. And also each of the rows is divided by 2.

$$n\left\{\begin{array}{cccccc} \multicolumn{6}{c}{\overbrace{\qquad\qquad\qquad}^{n}} \\ 1 & 0 & 0 & 0 & . & 0 \\ 0 & 1 & 0 & 0 & . & 0 \\ 0 & 0 & 1 & 0 & . & 0 \\ 0 & 0 & 0 & 1 & . & 0 \\ . & . & . & . & . & . \\ 0 & 0 & 0 & 0 & . & 1 \end{array}\right. \quad n\left\{\begin{array}{cccccc} \multicolumn{6}{c}{\overbrace{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}^{n}} \\ -2/(n-5) & 1/(n-5) & 1/(n-5) & 1/(n-5) & . & 1/(n-5) \\ 1/(n-5) & (n-6)/2(n-5) & -1/2(n-5) & -1/2(n-5) & . & -1/2(n-5) \\ 1/(n-5) & -1/2(n-5) & (n-6)/2(n-5) & -1/2(n-5) & . & -1/2(n-5) \\ 1/(n-5) & -1/2(n-5) & -1/2(n-5) & (n-6)/2(n-5) & . & -1/2(n-5) \\ & . & . & . & . & . \\ 1/(n-5) & -1/2(n-5) & -1/2(n-5) & -1/2(n-5) & . & (n-6)/2(n-5) \end{array}\right. \tag{A2}$$

Now we can see the proof of Proposition 3. Since there exists (n-5) as a denominator at all of the cells in equations of the right hand matrix in (A2), the inverse matrix degenerates when n=5.

The proof of Proposition 4 is given by this inverse matrix in (A2). When the parameter $q_i = (a - d_i)/b, (i = a, b,,, n)$, is normalized to unity (q_i=1, $(i = a, b,,, n)$, one can simply sum up each cell on a same row in the inverse matrix like the equations (4a), (6) and (8). The summation of the first row gives that (-2+(n-1))/(n-5)>0, if n>5. This means that the hub country can attain a positive production level when n is bigger than five. If n goes to infinite, the production level converges to 1.

The i-th row, which represents one of the spoke country, shows total production, or summation of the row of (2+(n-6)-(n-2))/2(n-5)=-6/2(n-5)<0, if n>5. This means that spoke countries suffer zero production levels, as long as the non-negative constraints bind the production level of the firm for spoke countries to maximize their profits. If n goes to infinite, the production level merely converges to zero.