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Inter-Provincial Railroad Network in China[1)]

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Abstract

Using Social Network Analysis (SNA), this paper examines the inter-provincial logistics relationships in China. Based on the annual data of inter-provincial railway logistics quantity during the period 1998-2009, the degree of interconnection between regions could imply intensified trends of regional economic integration.

The main results of the logistic relationships in China are as follows: the regional logistic interconnection, especially between western and eastern China has increased continuously, which would imply a rising national economic integration. However, the increased centralization index and the average Degree Centrality level imply that a logistics bottleneck has intensified in several hub provinces.

Secondly, logistic center provinces evaluated by the Degree Centrality have changed. In 2009, Hebei, Liaoning, Jiangsu, Shandong, Henan and Sichuan provinces revealed the highest inward Degree Centrality. Sichuan Province is the region that most surprisingly increased its centrality.

Thirdly, the number of logistic hub provinces, evaluated by the Degree Betweenness Centrality, has increased. In 2008, Henan province was only a focal hub but in 2009, Shandong, Hubei, Sichuan provinces became logistic hubs.

Lastly, the Community Modularity which analyzed grouping structures shows that there are three time-consistent communities. This means that even though there is enhanced between-region integration, the inter-regional inter-connection is more important in explaining the regional logistic relationship.

Keywords: *Rail Road Logistics in China, Degree of Centrality, Structural Hole*

JEL Classification Numbers : M19

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1. INTRODUCTION

We can never properly understand China's national economy without first examining its regional economies? However, there is little academic research conducted on China's regional economic interaction due to the lack of data availability and logics information related to intra and inter-regional economic activity. It is challenging to get a detailed provincial-level dataset and what is even more challenging is finding data on inter-regional economic relationships.[4] In addition, strong economic incentives from local governments create complex regional dynamics, which are not easy to interpret.

In regard to the regional economies in China, one of the focal issues is the national level of economic integration, which is closely related to the widening regional income gap, inefficient regional industry arrangements, over-investment in the local government, etc. Even though the Chinese government has implemented a series of policies to enhance regional integration, it is argued that these policies have had little effect in addressing the widening regional income gap.[5]

Detailed research on the inter-provincial logistical flow could be valuable information in understanding the trends in inter-provincial trade and regional integration. Considering the argument that an insufficient transportation infrastructure between regions could be a major factor hindering regional integration,[6] the logistics integration between regions will also give us useful information for uncovering regional economic trends in the future.

The salient difference in this research could be on the inter-provincial railway dataset, while most studies on Chinese railway logistics have analyzed geographic inferences using node-link locations of the stations and railways, and do not use the actual logistics quantity between nodes and links (Loo et al., 2005; Ru et al., 2008; Li and Cai, 2007).

As for the logistics network, by using Social Network Analysis (SNA), the complex logistics flow between 30 provincial level regions in China can be analytically summarized. The notion of centrality, which is widely used in SNA, will supply the basic understanding of changing trends in the logistics networks, the logistics status of each province and the overall feature of inter-provincial economic relationships.

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4) In past studies of inter-regional economic activity, only indirect data was used such as provincial level industry structures(Bai et al., 2004), provincial level international trade data(Naughton, 1999) or inter-provincial trade data between specific provinces and all other provinces(Poncet, 2003).

5) For example, during the mid 1990s to mid 2000s, the per capita income of the richest Shanghai Municipality to that of the poorest Guizhou Province exceeded 10.0. This is the largest reported income gap since the early 1980s.

6) Pittman(2004) argues that China's worsening pattern of income equality has a strong geographic component and that this is partly a problem caused by logistics.

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This paper focuses on the inter-provincial logistics network. The comparative logistics status of individual provinces will also be examined. In Section 2, the descriptive features of logistics trade among regions from 1998 - 2009 are described. In Section 3, using the Social Network Analysis, the general patterns of logistics centrality are examined. In Section 4, using the Structural Hole notion, the potential amelioration of the logistics network structure is analyzed. In Section 5, policy implications for China's logistics industry and future trends in logistics structures are drawn.

2. Regional Transitions of Logistics Networks

2.1 Data

The main data for this research is the inter-provincial railway logistics information which was gathered from the Statistical Yearbook Transportation group in China. It is composed of inward and outward volume (tons) for the individual provinces to and from other provinces, and it can be described as 30 by 30 matrices. To select a core network relationship, it has to be reduced to more simplified and meaningful network data, while preserving important network information. Based on the logistic quantity of the year 2009, every network link is coded from 0 to 4 (Table 1). The top 1% logistics link has a weighted code of 4, code 3 is the top 5%, code 2 is the top 10%, code 1 is the top 20% and a logistic quantity lower than the top 20% has a code of 0 which means these links will be ignored. Link reduction can be justified in the sense that the top 20% of the largest logistics links have more or less than 80% of the total logistics portion (table 2).

Table 1.
Link Reduction

Logistics quantity (10,000 tons)	Coding
Less than 211	0
212 to 547	1
548 to 1,420	2
1,421 to 5,181	3
More than 5,182	4

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Table 2.
Portion of logistics quantity

	1998	2001	2004	2007	2009
Top 1%	14.5	17.8	20.3	25.3	31.8
Top 5%	43.2	48.9	51.8	59.3	61.6
Top 10%	63.1	66.5	67.2	73.2	75.1
Top 20%	77.9	81.0	82.6	85.3	86.4

2.2 Descriptive features of logistics networks

The province which has the largest volume of outward logistics is Shanxi Province, which is the major coal mining province. Other large outward logistic provinces are Heilongjiang, Inner Mongolia and Liaoning Province which are also major production bases for natural resources. On the other hand, the largest inward logistic provinces are mostly located in the more developed, eastern coastal areas such as Hebei, Liaoning, Shandong, Jiangsu, and Tianjin.

Table 3.
Largest Logistic Provinces

Outward Logistics Quantity			
Ranking	1998	2004	2009
1	Shanxi (16.2)	Shanxi (18.6)	Shanxi (19.2)
2	Liaoning (7.9)	Heilongjiang (6.8)	Inner Mongolia (10.9)
3	Heilongjiang (7.9)	Liaoning (6.5)	Liaoning (6.6)
4	Hebei (7.0)	Inner Mongolia (6.3)	Shandong (6.0)
5	Shandong (6.3)	Hebei (6.3)	Heilongjiang (6.3)
Inward Logistics Quantity			
Ranking	1998	2004	2009
1	Hebei (11.1)	Hebei (13.1)	Hebei (17.4)
2	Liaoning (10.0)	Liaoning (9.6)	Liaoning (9.7)
3	Shandong (6.8)	Shandong (7.2)	Shandong (7.0)
4	Heilongjiang (6.2)	Jiangsu (5.4)	Heilongjiang (5.2)
5	Jiangsu (5.4)	Tianjin (4.8)	Henan (4.5)

Note: The numbers in parenthesis are the portion of total logistics activity in 30 provinces.
Source: Statistical Yearbook of Transportation in China, Years 1998 to 2009.

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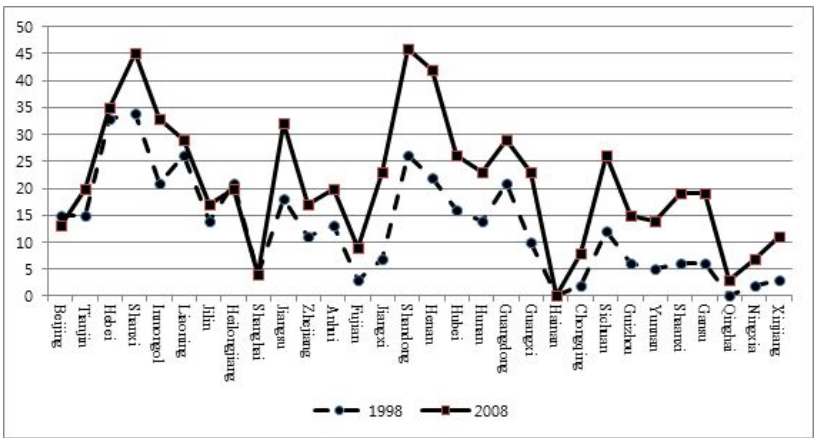
Even though the rankings of the largest inward and outward logistics provinces have altered very little, the overall features of the inter-provincial connection have changed remarkably. Firstly, the inter-provincial connection on the whole has increased. During the period of 1998-2009, the Degree of Connection, with the exception of a few provinces such as Shanghai and Hainan, has increased resulting in more direct logistic exchanges with other provinces (figure 1).

Secondly, the interconnection between western provinces and eastern coastal provinces has remarkably been reinforced. In 1998, most of the western and southern provinces were comparatively isolated in the criteria of the top 20% logistics quantity in the year 2009. However, in 2009, the western and southern provinces (except Qinghai Province) had multiple logistic relationships with neighboring provinces (figure 2, 3).

In the sense of increasing logistics connections, the most salient province appears to be Sichuan Province. In 1998, Sichuan Province had several interconnects with neighboring provinces, but by 2009, it had multiple interconnections with western, southern and mid-eastern provinces, which points logistically to Sichuan Province being a western hub province. This trend might be easily recognized in the sense that Sichuan Province is the core of 'West China Development'. To address the widening regional income gap, the 'West China Development' plan, the first regional development plan, was launched in the mid 1990s. The key measure for the 'West China Development' plan was to invest in infrastructure for logistics interconnection.[7)]

Figure 1.
Degree of Connections from 1998 to 2009



Note: The Degree of Connections is the sum of inward and outward direct links.

7) A typical example of investment in the logistics infrastructure was the Qingzang railway. It was completed in 2006, is 1,956 km long and is one of the highest elevation railroads in the world. The construction of the Qingzang railway was one of the four mega infrastructure programs in the 'West China Development' plan.

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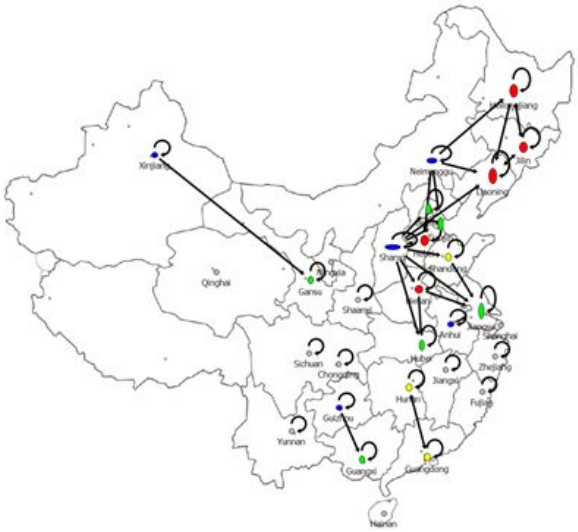
Figure 2.
Degree of Inter-Province Connections in 1998



Note: The larger the circle, the larger the logistics network links. The round arrows indentify the inside provincial logistics areas which are in the top 20%.

Figure 3.
Degree of Inter-Province Connections in 2009

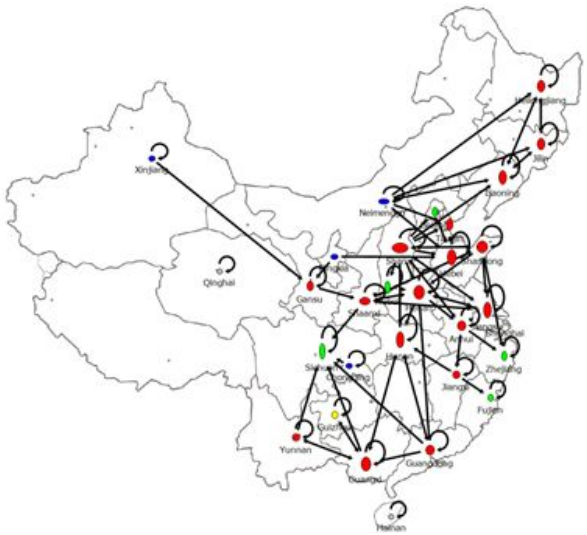


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Figure 4.
Direct Links for Sichuan Province in 1998

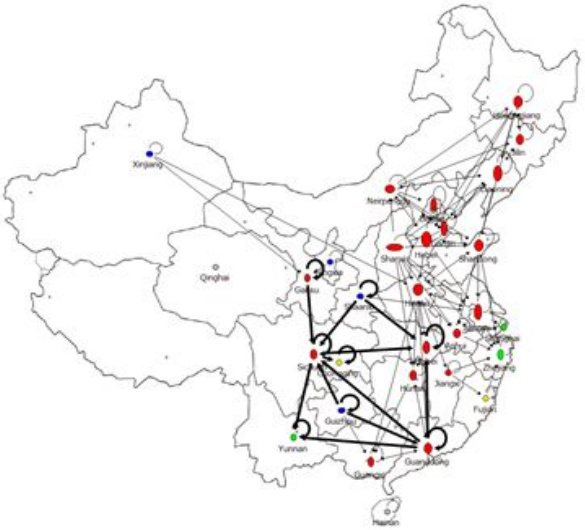
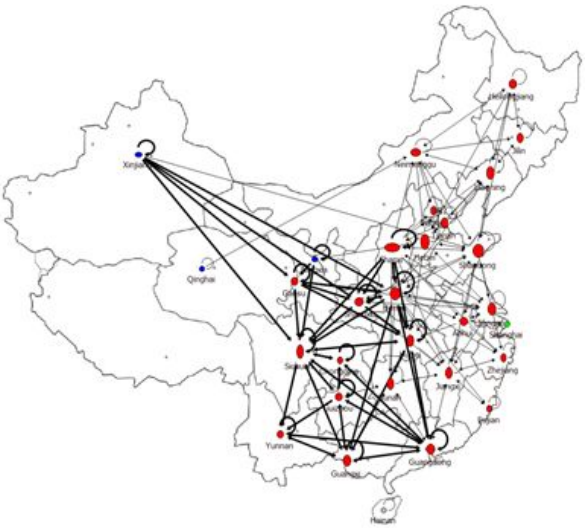


Figure 5.
Direct Links for Sichuan Province in 2009



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3. Logistics Positions for Railroad Transportation by Provincial Level

3.1 Degree Centrality

To examine the comparative logistic positions among 30 provinces, Degree Centrality, Betweenness Centrality and Community Structure must be examined using the Social Network Analysis (Ducruet et al., 2011; Kim et al., 2011).

Degree Centrality is measured from the weighted links which are directly connected with each node, so the heavier the directed linked node, the higher the Degree Centrality. It is recognized as an index for a local logistics center in the sense that the index of each province may be higher when a more directly linked logistics quantity is concentrated.

To find the logistic center, we specially presented the inward Degree Centrality. The provinces which have heavier inward flows of logistics quantity can be more easily interpreted into a logistics center in the sense that it is a region where logistics quantity is gathered and re-distributed (Boegatti, 2009).

In <figure 6>, the top six provinces for inward Degree Centrality are presented. The eastern coastal provinces, except Sichuan Province, have the highest inward Degree Centrality. It is easily shown that all provinces have steadily augmented inward Degree Centrality. This means that the logistics position as the center for inflowing, assembling and redistributing commodities has intensified. In addition, it basically implies an intensified inter-provincial logistics connection.[8)]

By analytical comparison, Sichuan Province has strikingly enhanced its logistical position. This enhancement may be due to two different factors. One factor is that Sichuan Province is the center where natural resources in western China are gathered and re-supplied to eastern China. The other factor could be its huge infrastructure project which requires an enormous amount of materials to be supplied from developed regions.

However, while the connectivity among regions has continuously intensified, the overall network centralization and the average centralization index for all provinces have increased (figure 7). The centralization index has increased where network flows are concentrated to several of the nodes. So rising network centralization means that heavier logistics burdens have been brought into these logistics centers.[9)] That is to say, Bottlenecks are likely to occur in these logistics center provinces.

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8) Wang (2009) also shows an integrated trend of railway networks, which is due to national-level economic development and the formation of additional urban areas.

9) Many researchers have found that Chinese railway networks are not very developed. That is to say, many nodes have a small amount of connectivity, while only a few nodes have key roles in the overall network (Ducruet et al., 2011; Li and Cai, 2007; Wang et al., 2009; Wang we al., 2008)

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Figure 6.
Top 6 provinces for Inward Degree Centrality

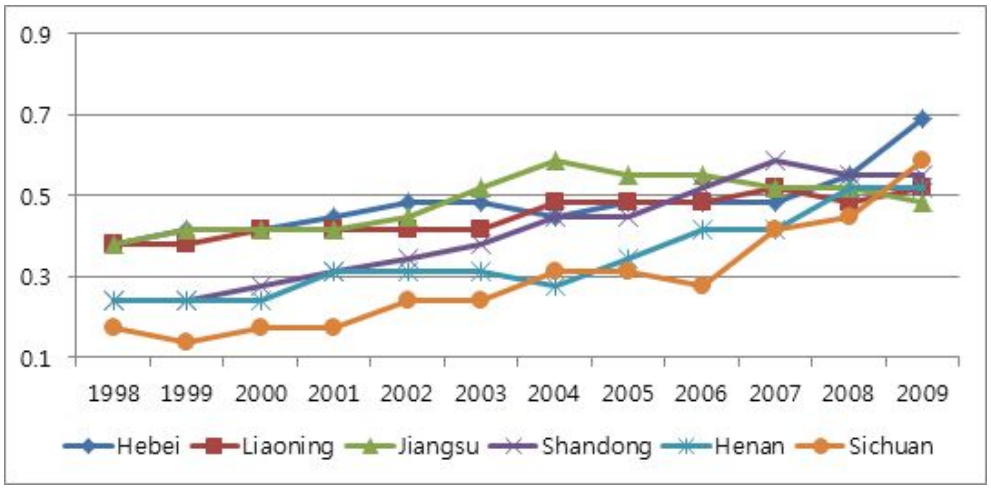
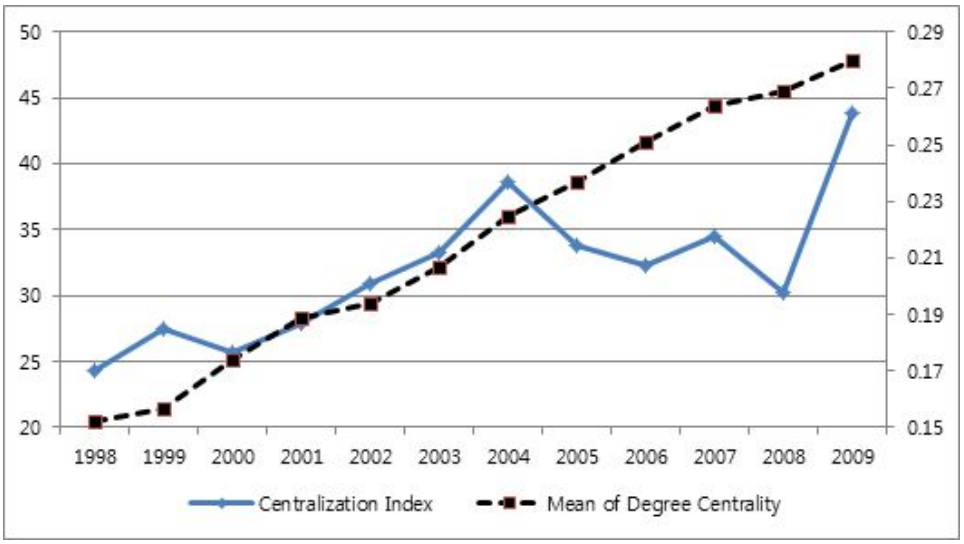


Figure 7.
Trend of overall Centralization



3.2 Betweenness Centrality

Among many Centrality measures, Betweenness Centrality contains an analytic notion for measuring logistic hubness. Betweenness Centrality calculates the statistical probability that a specific node is located on the shortest path of two random nodes in

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the network. That is to say, if a node has the highest Betweenness Centrality, the network flow will pass the node in most cases.[10] In the logistics context, a province with the highest Betweenness Centrality has the highest probability that commodities will pass through the province.

Henan Province appeared to be a unique logistic hub in the sense that it had the highest Betweenness Centrality in 1998 (figure 8). However, in 2009, mostly due to the increased logistics flows and a denser logistics infrastructure between regions, Henan Province lost its distinguished position as a railway logistics hub. In the meantime, Hubei, Shandong and Sichuan Province have emerged as multiple logistics hubs (figure 9).

Importantly, this result contradicts with research which argues that the East China region outperforms Central China, which in turn surpasses Western China (Loo and Liu, 2007;Wang et al., 2009). However, it has to be mentioned that this research is generally based on the geographic factors, and does not consider the actual inter-provincial flows of logistics quantities.

Interestingly, there are several implications for logistics hubs in China. Firstly, logistic hubness can be obtained by several different reasons. As for Henan and Hubei Provinces, their hubness is mainly due to their location advantages, these two provinces are placed in central China where they have obviously more chances for commodities to be passed. However, for Sichuan Province, the policy propriety appears to have more influence on its hubness. The hubness of Shandong Province is due to its abundant resources and developed economy.

Secondly, captured in the conceptual graph of Betweenness Centrality (figure 8, figure 9), hubness is generally organized based on several clusters. For example in 1998, Henan Province has the highest position while Guangdong, Shandong and Hubei provinces have subordinate provinces such as the south west provinces in Guangdong, the North east provinces in Shandong and the Mid west and east provinces in Hubei.

Thirdly, by also using Betweenness Centrality, Sichuan Province remarkably enhanced its logistics position during the period 1998-2009. It is important to note that Sichuan Province is one of the most frequently passed logistics nodes in spite of its remote geographic status, which implies that inter-provincial logistics have become more integrated.

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10) The betweenness of node i is calculated by $\frac{\sum_{j_i k} g_{j_i k}(n_i)/g_{j_i k}}{(a-1)(a-2)/2}$, whereas $(a-1)(a-2)/2$ means the number of node pairs that do not pass node i, $\sum_{i_i k} g_{j_i k}(n_i)/g_{j_i k}$ means the probability that node i is located in the shortest path between node j and node k.

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Figure 8.
Betweenness Centrality in 1998

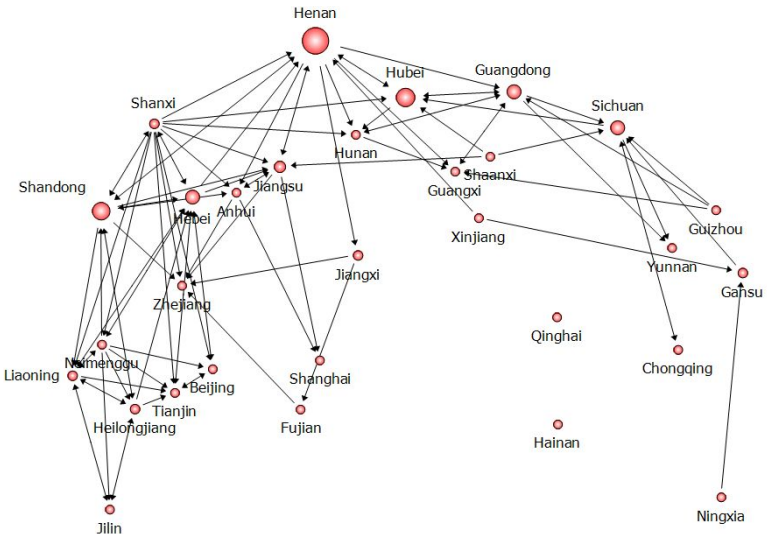
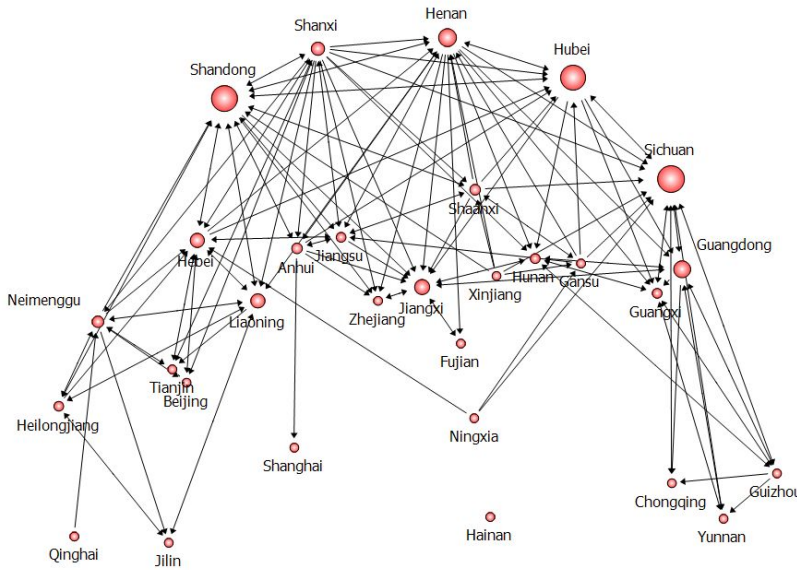


Figure 9.
Betweenness Centrality in 2009



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3.3 Group Structure

By grouping an analysis of Community Modularity, the provinces can be grouped into three communities. Community Modularity is one of the tools used to capture group structure, which analytically classifies the same group. If the number of links within the group is larger than those outside of the group, the nodes can be grouped into the same group ex post.

By using Community Modularity, Chinese provinces can be grouped into three communities; Northern China, Mid China and Southern China (figure 10). Interestingly these community groupings did not change during the period 1998-2009. That is to say, even though there were more integrated trends for inter-region logistics networks, the Northern provinces are more closely inter-connected than the provinces outside of the Northern regions.

These time-consistent community structures imply that Chinese provinces or regions have a strong tendency for integration within the region, and disintegration outside of the region. So the national level unified economy or market still has a long way to go. But on the other hand, based on the fact that there has been a growing between-region integration trend, and large amounts of money have been invested on infrastructure, it has still maintained the time-consistency trend. We can argue that these three community structures continue to maintain the best way.

The three community structure could also infer to policy implication that there are several regions for the policy priorities in building the railway infrastructures and networks. If we select the railways which are rated in the top 10% in logistical quantity, it reveals several weak links (figure 10).

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Figure 10.
Community Structure in 2009

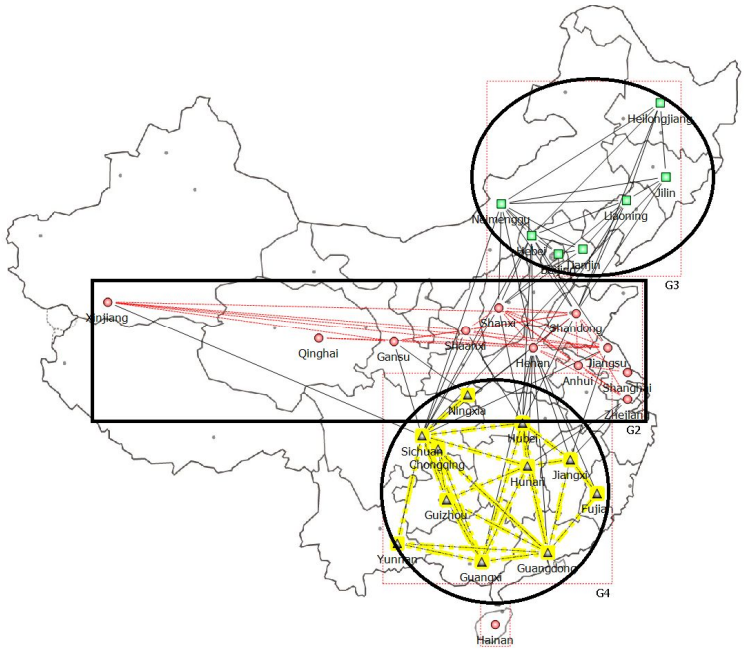

Figure 11.
Weak links in the Chinese railway network in 2009

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4. Policy Implications and Concluding Remarks

Using Social Network Analysis (SNA), this paper examines the inter-provincial logistics relationships in China. Based on the annual data of inter-provincial railway logistics quantity during the period 1998-2009, the degree of interconnection between regions could imply intensified trends of regional economic integration.

The main results of the logistics relationships in China are as follows: the regional logistics interconnection, especially between western and eastern China has increased continuously, which would imply rising national economic integration. However, the increased centralization index and the average Degree Centrality level imply that a logistics bottleneck has intensified in several hub provinces.

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Lastly, the Community Modularity which analyzes grouping structures shows that there are three time-consistent communities. This means that even though the enhanced between-region integration, inter-regional inter-connection is still the best way to explain the regional logistic relationships.

Overall evaluations of the Chinese regional logistics relationships can be very positive in the sense of their enhanced inter-provincial integration levels. However, the increased burdens on several of the logistics center provinces as well as the increased centralization in the overall network may require a more efficient and more widely dispersed network construction.

The three community structure did not change during the period 1998-2009. This means that regional disintegration is still an ongoing issue which needs to be addressed through academic and policy-based measures.

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