Risk Spillover of the Real Estate Sector Through the Input-Output Network Based on Inter-Sectoral Production Linkage

Abstract: Production linkage is one of the most prevalent interconnections between economic agents, and thus one of the most important risk transmission channels between companies and sectors. Due to the existence of inter-sectoral or inter-company linkages, the risk spillover effect from one company being in default to its related sectors is highly likely to occur through direct financial transactions, information dissemination, sentiment contagion and so on, and in some extreme cases even lead to nearly complete collapse of the whole industrial chain. As a pillar sector of the national economy, the real estate sector has a long industrial chain where there are many companies in various sectors, from upstream building materials to downstream home appliances, furnishings and decorations, penetrating almost every corner of the economic system. These companies in the industrial chain have established complex production linkage due to the credit-and-debt relationship in business transactions, joint cooperation in development or sales of the same product, which have generated financial interconnections, information dissemination and sentiment contagion. These complex production relationships potentially spill over the default risks in the real estate sector to its related sectors, and even further trigger systemic risks, which poses a great threat to the stable development of the entire economic system. The outbreak of several financial crises in history has been highly related to the risk spillover of the real estate sector. Therefore, it is important and urgent to explore the risk spillover effects of the real estate sector from the perspective of input-output production linkage.

Therefore, this paper constructs an input-output network between the real estate sector and other sectors based on the inter-sectoral production linkage illustrated by input-output tables, and quantitatively analyzes the impact of real estate sector risks on its related sectors based on the input-output network, specifically, the influence on sectors in the input-output network, such as the construction sector, when the real estate sector generates default risks or when real estate prices fluctuate drastically. Strategies for preventing and alleviating risk spillover in the real estate sector are provided based on the analysis of the input-output network. In this paper, the input-output table of 42 sectors in China from 1998 to 2018 are used to calculate the coefficients and other indicators of the real estate sector and other sectors, and then a directed input-output network of the real estate sector and other sectors is constructed with these indicators. Accordingly, we analyze the spillover effects and risk transmission paths of the real estate sector on other sectors and find that: (1) the real estate sector does not have strong risk spillover effect on all industrial sectors, but has significant risk spillover through the input-output network to the financial sector, the typical upstream sector -- construction sector, and the typical downstream sector -- wholesale and retail trade sector; (2) the

risk spillover of the real estate sector to other upstream and downstream sectors through the input-output network is affected by the real estate industrial cycle. This paper integrates input-output analysis and complex network analysis to study the risk spillover effect of the real estate sector from the perspective of production linkage, which expands the application of input-output analysis methods and enriches the theories and methodologies in financial risk research, and is of great theoretical significance.

Keywords: Input-output network, real estate sector, production linkage, risk spillover

I. Introduction

In recent years, there have been frequent risk crisis events in the real estate sector. According to Wind database, based on the CSI 300, a total of 93 bonds have defaulted (including all types of material defaults and extensions) as of the first half of 2022, with a total default amount (including principal and interest) of 60.1 billion yuan, involving 33 credit bond subjects. Among them, 12 new default subjects, of which 7 are companies in the real estate sector, accounting for nearly 60%. It can be seen that the real estate sector is the main source of default events. According to the annual report released by People's Bank of China, as of the end of 2022, the balance of RMB real estate loans3 was 53.16 trillion yuan, a year-on-year increase of 1.5%, 6.5 percentage points lower than the growth rate at the end of the previous year; an increase of 721.3 billion yuan for the whole year, accounting for 3.4% of the increase in various loans in the same period. The balance of real estate development loans was 12.69 trillion yuan, an increase of 3.7% year-on-year, 1.5 percentage points higher than the end of the third quarter and 2.8 percentage points higher than the end of the previous year. The balance of personal housing loans was 38.8 trillion yuan, an increase of 1.2% year-on-year, and the growth rate was 10 percentage points lower than the end of the previous year. There are also a large number of bonds, equity, trusts and other funds into the real estate sector, and real estate is deeply related to the financial sector. Real estate is the biggest "gray rhinoceros" in terms of financial risk.

The industrial chain related to the real estate sector is long and fairly complex. For the spread of risks in the real estate sector, there are many companies from various industries in the long industrial chain of real estate sector from the perspective of production, from upstream building materials to downstream home appliances and furnishings, construction and decoration, etc., which penetrate almost every corner of the social economy. Therefore, changes in the real estate sector usually have a large impact on many related industries and affect the stable and coordinated development of the macroeconomy (Wang and Liu, 2004). In 2020, due to the outbreak of the epidemic, the return of workers in many companies was delayed, sales offices in the housing market were closed, and the trading was stalled, resulting in poor cash flow, a great amount of default and even closures of companies in the real estate industrial chain. Therefore, in order to safeguard people's livelihood, it is of vital significance to construct an input-output network of production relations between the real

estate sector and upstream and downstream industries, measure and simulate the spillover of risks, and thus formulate corresponding policies for the prevention and control of risks accordingly.

Based on this background, this paper constructs input-output networks through input-output tables from the perspective of complex networks, grasps the production linkages and analyzes how the risks in the real estate sector affect other industries through this transmission channel, so as to formulate appropriate response strategies for risk spillover in the real estate sector.

II. Literature Review

In the traditional studies of risk spillovers in the real estate sector, the existence of risk spillover effects has been confirmed between real estate and sub-sectors in the financial markets such as banking, securities and insurance (Pais and Stork, 2011; Fang, Yi, 2018; Zhang et al, 2019; Damianov and Elsayed, 2018; Chiang and Chen 2022).

Regarding the research approach of risk spillover in the real estate sector, many scholars have adopted the perspective of production linkage, arguing that the real estate industry, with its large financing volume and long industrial chain, has extensive, close and complex production linkage with other national economy industries, and therefore production linkage should be focused as a way to study risk spillover in the real estate industry. Chan et al. (2016) found that based on input-output analysis, the real estate and financial linkages between the industry and other sectors have been strengthened, and the DAG approach and SVAR were used to demonstrate that credit risk in the real estate industry had large-scale spillover effects on other industries. Di Giovanni and Hale (2022) decomposed the total impact of U.S. monetary policy on global equity returns into direct and network effects using a SAR model, demonstrating that nearly 70% of the total impact came from network effects of global production linkages. Based on the TENQR model, Xu et al. (2022) investigated the structure of industry chains and demonstrate that upstream industries dominate risk diffusion under extreme market conditions.

Currently, complex networks have been one of the common approaches to study risk spillovers in finance. Scholars usually construct complex networks to explore cross-market risk spillovers. Liu et al. (2017) used spillover indices and complex network methods to measure the intensity and direction of risk spillover in China's financial market; Using a minimum spanning tree (MST) approach, Liu et al. (2018) constructed a financial network with data related to the financial crisis period of 2007-2009, further demonstrating that the current financial system had obvious nonlinear complex system characteristics and made the cross-market propagation of risk more complex under multiple feedbacks, and that the degree of correlation among submarkets within the financial market during the financial crisis was significantly strengthen. Some scholars have also applied the idea of network model to construct credit risk contagion model and credit stress propagation network by taking risk-averse sentiment and liquidity, average adaptation of credit risk contagion as the entry

point, respectively (Chen and Anagnostou et al., 2017). Yang et al. (2017) combined the core-edge network with the adjacency matrix to construct the contagion model and simulate external shocks to explore the risk contagion in the interbank market. Gong and Xiong (2020) used variance decomposition network approach to construct up information spillover complex networks and analyze the risk contagion characteristics within the financial system from the network perspective. Based on empirical evidence from the global market during the financial crisis, Zhang and Sun (2020) statistically described the network characteristics through complex network theory and construct a network graph using the minimum spanning tree (MST) method to study the topological characteristics of the complex network in the global stock market, the transmission mechanisms and paths of cross-market financial risks in the context of the financial crisis. Long et al. (2022) combine KVM and MST methods to construct a credit risk network of the real estate industry based on default risk measures of listed companies in the industry from 2015-2018 in order to analyze the risk contagion effect of the real estate industry.

In summary, the theoretical study of risk spillover in the real estate industry is relatively mature, and the existing literature has made an adequate study of the basic concept and transmission mechanism of risk spillover effect. However, there are still certain research gaps: from the research content, the existing literature has been mostly limited to the risk spillover effect of the real estate sector on the banking industry or a separate industry, while there is less research on the risk spillover effect of the real estate sectors on other industries at the same time. And the current literature is limited to the study of spillover between the real estate market and the financial industry, while there is less research on the spillover of risk between the real estate industry and the industries in the real economy; in terms of research methods, when it comes to the application of complex network methods in the real estate field and even in the context of the entire financial market, the construction of complex networks generally relies on capital linkages, such as investment and financing linkages and lending linkages, etc. Fewer scholars have used input-output tables to construct complex networks of inter-industry production linkages to illustrate the ways through which risks spill over when risk events occur in the real estate industry.

III. Network Construction

3.1 Indicator Selection

In order to intuitively display the magnitude of the association between China's real estate sector and other sectors in the input-output table, this paper calculates the direct consumption coefficients between sectors to represent the strength of the techno-economic linkages between the real estate sector and other sectors, and the complete consumption coefficients to represent the indirect techno-economic linkages between sectors of the national economy, based on the input-output table for the period 1997-2020.

In this paper, the direct consumption coefficient is expressed by $a_{ij} = \frac{X_{ij}}{X_j}$, (1)

where, a_{ij} refers to the value of the product of sector i consumed directly by sector j in the production process of one product of sector j; X_{ij} represents the amount of goods or value of sector i consumed directly by sector j in the production process; X_j represents the total input of sector j.

From the definition and calculation of direct consumption coefficient, it can be seen that the values of direct consumption coefficient range between 0 and 1, that is, $0 \leq a_{ij} < 1$. The larger the a_{ij}, the stronger the direct dependence of sector j on sector i; conversely, the smaller the a_{ij}, the weaker the direct dependence of sector j on sector i. The $a_{ij} = 0$ means that sector j has no direct dependence on sector i.

To better observe the amount of value of goods and services that the end use of the real estate sector requires to fully consume in each sector, the coefficient of full consumption is also calculated in this paper. The complete consumption coefficient is then denoted by b_{ij}:

$$b_{ij} = a_{ij} + \sum_{k=1}^{n} a_{ik}a_{kj} + \sum_{s=1}^{n}\sum_{k=1}^{n} a_{is}a_{sk}a_{kj} + \sum_{t=1}^{n}\sum_{s=1}^{n}\sum_{k=1}^{n} a_{it}a_{ts}a_{sk}a_{kj} + \cdots, (i, j = 1,2, \dots, n) \quad (2)$$

where b_{ij} represents the sum of direct and indirect consumption of goods or services in sector i for each unit of end use provided by sector j; a_{ij} represents the direct consumption of sector i by sector i; the second term in the equation $\sum_{k=1}^{n} a_{ik}a_{kj}$ represents the first round of indirect consumption of sector i by sector j; the third term in the equation $\sum_{s=1}^{n}\sum_{k=1}^{n} a_{is}a_{sk}a_{kj}$ is the second round of indirect consumption; and the fourth term $\sum_{t=1}^{n}\sum_{s=1}^{n}\sum_{k=1}^{n} a_{it}a_{ts}a_{sk}a_{kj}$ represents the third round of indirect consumption. And so on, the nth+1th item is the nth round of indirect consumption.

3.2 Network Construction Based on the Input-Output Tables

In the existing research on the problem of risk contagion path identification, most scholars use the minimum spanning tree (MST) algorithm, which is to construct a network generated by a distance matrix such that the MST network has the smallest sum of connected edge distances among all network graphs. Therefore, the MST algorithm can well visualize the diffusion process of risk in a network. However, the shortest path spanning tree (SPT) algorithm, compared with the MST algorithm, guarantees that the root is the source and the path from the source to all vertices is the shortest path from the source to all vertices, which is more suitable for simulating the scenario in a directed network when a risk spillover occurs at a vertex in the network and how the risk is transmitted to each vertex in the shortest path. Currently, SPT algorithms are more often used in the field of economic finance in the area of supply chain management and less often in the financial risk contagion problem.

Shortest path tree (SPT) algorithm is a kind of data structure tree generated using shortest path algorithm. It can be mainly divided into Dijkstra's algorithm and Floyd's algorithm. Among them, Dijkstra's algorithm is more commonly used, and Dijkstra's algorithm will also be used in this paper for shortest path spanning tree analysis. The algorithm sets two sets of fixed points T and S. The set T stores the fixed points of the shortest paths found, and the set S stores the fixed points of the shortest paths not yet found. In the initial state, the set T contains only vertex v. After that, the vertex u with the shortest path length to vertex v is continuously selected from the set T and added to the set S. Each new vertex u added to the set S modifies the value of the shortest path length from vertex v to the remaining vertices in the set T. The new shortest path length of each vertex in the set T is the value of the shortest distance from the vertex u just added to the original vertex and the value of the distance from the original vertex to the vertex v and the smaller value of the distance from the vertex u to the vertex v that has just been added. This process is repeated until all the vertices of the set T are added to the set S. The specific computational logic of the algorithm is as follows:

Input assigned directed graph G = (V，E，W)，V = $\{v_1, v_2, \cdots v_n\}$，s := v_1

Output: shortest path from source s to all $v_i \in$ V \ {s}

1. initially S = $\{v_1\}$;

2. compute dist[s, v_1] for $v_i \in$ V - S;

3. choose $min_{v_j \in V} dist[s, v_i]$ and put v_j into the set S and update the dist values of the vertices in V - S;

4. repeat step 1 until S = V.

For the construction of complex networks, this paper uses the direct consumption coefficient as the index to measure the correlation between vertices which represent the sectors in the national economy. When searching for SPT networks in complex networks, the direct consumption coefficient is chosen to be used as edge weights. This is because when performing shortest path spanning tree, the path length needs to be calculated and the result of the calculation takes the shortest path between the source vertex to the target vertex, and finally generates the shortest path spanning tree from the specified vertex to all vertices. When the contagion of risk in the real estate sector occurs, it is likely to spread from this sector to the most closely related sectors first. If the direct consumption coefficient is used as the edge weight, the higher the edge weight between two vertices in the input-output network, the higher the correlation between the two sectors. However, the larger the edge weights are, the longer the paths will be, and the production sectors that are less correlated will be filtered out when using the shortest path spanning tree algorithm. Therefore, in this paper, we choose to use the inverse of the direct consumption coefficient of the 1997-2020 input-output table as the side weights when constructing the input-output network.

3.3 Network Characterization

This paper constructs the input-output network among sectors based on the calculated direct consumption coefficient and complete consumption coefficient. To obtain more information from the network, the topology of the input-output network is analyzed by calculating the indices displaying network characteristics such as the out-degree centrality index, in-degree centrality index, network density, average path length and network clustering coefficient.

A. Betweenness Centrality

Betweenness Centrality (BC) measures how often each vertex appears on the shortest path between two vertices in the graph, and can be used in this paper to characterize the efficiency of information transmission at that vertex. When multiple shortest paths pass through a vertex at the same time, the vertex has an important mediating effect and has a key controlling and regulating role on information dissemination in the network. The equation for the intermediary centrality is:

$$BC_i = \sum_{s,\ t \neq u} \frac{n_{st}(i)}{N_{st}} \quad (5)$$

where, $n_{st}(i)$ is the number of shortest paths from s to t and through vertex i, and n_{st} is the total number of shortest paths from s to t.

B. Network Density

Network Density (Den) is used to characterize the density of interconnected edges between vertices in an input-output network, and is defined in this paper as the ratio of the number of edges actually present in the network to the number of possible links between all vertices. The equation for network density is shown in Equation (6):

$$DEN = \frac{2L}{N(N-1)} \quad (6)$$

where L is the actual connected edges in the network and N is the number of vertices.

Since the input-output network constructed in this paper is a directed network, the formula for network density is written as:

$$DEN = \frac{L}{N(N-1)} \quad (7)$$

C. Average Path Length

The average path length (APL) of a network, also known as the characteristic path length or average shortest path length, is defined as the average of the distance between any two vertices in the network, i.e., the average of the shortest path lengths (or distances) between two vertices in a network. From a vertex i, through the vertices connected to it, and gradually "walk" to another vertex j through the path. The formula for calculating the average path length is:

$$APL = \frac{2}{N(N-1)} \sum_{i \geq j} d_{ij} \quad (8)$$

where N is the number of vertices in the network and d_{ij} represents the number of connected edges on the shortest path connecting vertices i and j. It is also called the geodesic distance or jump distance between two vertices.

D. Clustering Coefficient

Clustering Coefficient (Clu) in a network is defined as the probability that any three vertices are connected to each other two by two, reflecting the closeness of the network. It can be analyzed whether the shape of the network is regular coverage and concentration, and is an important way to understand the whole structure of the network. The clustering coefficient of vertex i can be expressed as:

$$Clu_i = \frac{2L_i}{[N_i(N_i-1)]} \quad (9)$$

In this paper, the average of local clustering coefficients of all vertices is taken as the overall clustering level of the network:

$$\overline{Clu_t} = \frac{1}{N} \sum_{i=1}^{N} Clu_i \quad (10)$$

where Clu_i is the clustering coefficient of each vertex. $\overline{Clu_t}$ represents the average clustering coefficient of the input-output network in year t.

IV. Network Analysis

4.1 Data Selection

The data for this study are obtained from a total of 10 input-output tables from 1997 to 2020 in China. Among them, the input-output tables from 1997 to 2018 are from the Input-Output Association, and the input-output table data for 2020 are from the National Bureau of Statistics. This sample interval is chosen because it contains three major cycles of China's real estate sector and key points of real estate market regulation. For example, in 1998, the "housing reform" policy was introduced, and China's real estate gradually entered a period of market activation; in 2003, the People's Bank of China issued *Notice on Further Strengthening the Management of Real Estate Credit Business*, which was the first measure taken by the Chinese government to curb the overheating of the real estate sector; in 2008, the global financial crisis broke out due to the U.S. subprime mortgage crisis, and China's real estate sector entered a freezing period. The Chinese government began to rescue the market again and started the second de-stocking; in 2017, real estate ushered in the toughest regulation year, with more than 100 cities releasing property market

regulation policies from March to November. Therefore, these 10 input-output tables can almost cover the changes in China's real estate sector and thus analyze the impact of fluctuations in the real estate sector on other sectors.

4.2 Production Linkage Analysis

A. Indicator Calculation and Analysis

After calculating the direct consumption coefficients using the sample data, the direct consumption coefficients between the real estate sector and other sectors are ranked. It can be seen through Tables 1-10 that the sectors of finance and insurance, construction, leasing and business services, and electrical machinery and equipment manufacturing have close production linkage with the real estate sectors during 1997-2020. The production and supply of electricity and heat, information transmission, software and information technology services, transportation, storage and postal services, as well as communications equipment, computers and other electronic equipment sectors also have high rankings, indicating that the real estate sector can directly or indirectly pull these sectors, thus further reflecting the characteristics of the real estate sector's wide range of connections and long industrial chain. As of 2005, the construction sector and the leasing and business services sectors were in the second and third place respectively. Since 2005, the real estate sector's direct consumption of leasing and business services has exceeded that of the construction sector.

The direct consumption coefficient of the real estate sector to the financial sector has been in the first position for years, indicating that the real estate sector is inseparable from the financial sector. This is because of the need for support from the financial sector in the development and sales process of the real estate sector. The real estate sector has a relatively long production cycle and uses a large amount of capital. Relying only on the developer's own capital and without the support of the financial sector, the real estate sector cannot develop so rapidly. Therefore, during the development phase, real estate companies make borrowings, which are beneficial for expanding the business volume of the financial sector. The real estate sector, on the other hand, cannot develop without the support of the financial sector, which is also needed during the sales phase of the real estate sector. Housing mortgage is one of the ways in which the real estate sector consumes the products or services of the financial sector.

From the perspective of temporal trends, between 1997 and 2005, the production linkage between the real estate sector and sectors with production linkages became stronger, as was shown by the rising direct consumption coefficient. However, in 2007 the country started to adopt a tightening financial policy, with the central bank raising the interest rate benchmark, increasing interest rates and raising the reserve rate. Six months later, the global financial crisis broke out due to the impact of the U.S. subprime mortgage crisis, and the real estate sector entered a freeze period. As a result, in 2007 the real estate sector reduced the level of material consumption in the financial sector,

construction sector, leasing and business services, non-metallic mineral products sector and other sectors.

In 2008, the real estate market was affected by the subprime mortgage crisis and the Chinese government introduced a series of rescue policies, housing prices stopped falling and rose again in 2009. Therefore, the direct consumption coefficient of real estate sector to other related sectors increased after 2010 compared with 2007, and the direct consumption coefficient table in 2012 showed that the direct consumption coefficient of real estate market to financial sector increased significantly because the People's Bank of China lowered the interest rate twice in 2012, and the loose monetary policy made the sales and real estate sector rebound. In addition, the correlation between other related sectors and the real estate sector also increased, which indicates that the policy was positive for the real estate sector in 2012. In the following years, after the recovery in 2012, the hotness in 2013, the silence in 2014, the rise in 2015 and the soar in 2016, the production association of the real estate sector with other sectors continued to rise and the direct consumption coefficient showed an increasing trend.

finance and insurance, construction, leasing and business services, and electrical machinery and equipment manufacturing have close production linkage with the real estate sectors during 1997-2020. The production and supply of electricity and heat, information transmission, software and information technology services, transportation, storage and postal services, as well as communications equipment, computers and other electronic equipment sectors

Table 1 Top ten direct consumption coefficients in China's real estate sector, 1997-2002

1997		2002	
Sectors with top 10 coefficients	coefficients	Sectors with top 10 coefficients	coefficients
Finance and insurance	0.0461	Finance and insurance	0.0775
Construction	0.0389	Construction	0.0405
Non-metallic mineral products	0.0389	Leasing and business services	0.0369
Social services	0.0211	Accommodation and catering	0.0144
electrical machinery and equipment manufacturing	0.0090	Non-metallic mineral product	0.0119
Business	0.0087	Real estate	0.0096
Other manufactures	0.0080	Transportation and storage	0.0093
Paper printing and stationery manufacturing	0.0069	Transportation	0.0085

Catering	0.0067	Electrical machinery	0.0084
Real estate	0.0060	Generals	0.0072

Table 2 Top ten direct consumption coefficients in China's real estate sector, 2005-2007

2005		2007	
Sectors with top 10 coefficients	coefficients	Sectors with top 10 coefficients	coefficients
Finance and Insurance	0.0493	Finance and Insurance	0.0248
Leasing and Business Services	0.0367	Leasing and Business Services	0.0219
Construction	0.0200	Construction	0.0122
Accommodation and catering	0.0132	Chemical Industry	0.0115
Electricity and heat production and supply	0.0105	Accommodation and catering industry	0.0109
Non-metallic mineral products	0.0099	Petroleum processing and coking, nuclear fuel processing industry	0.0091
Transportation and storage	0.0083	Real estate industry	0.0089
Electrical machinery and equipment manufacturing	0.0062	Electrical machinery and equipment manufacturing	0.0081
Real estate industry	0.0056	Metal products industry	0.0076
Transportation equipment manufacturing	0.0054	Residential services and other services	0.0062

Table 3 Top ten direct consumption coefficients in China's real estate sector, 2010-2012

2010		2012	
Sectors with top 10 coefficients	coefficients	Sectors with top 10 coefficients	coefficients
Finance	0.0432	Finance	0.1052
Leasing and Business Services	0.0340	Leasing and Business Services	0.0400
Construction	0.0194	Real Estate	0.0321
Chemical Industry	0.0168	Construction	0.0240
Accommodation and Catering	0.0164	Transportation, storage and postal services	0.0059

Real Estate Industry	0.0133	Paper, printing, education and sporting goods industry	0.0051
Petroleum processing, coking and nuclear fuel processing industry	0.0132	Electricity, heat and power production and supply	0.0048
Electrical machinery and equipment manufacturing	0.0112	Accommodation and catering	0.0047
Transportation and storage	0.0076	Information transmission, software, and information technology services	0.0042
Residential services and other services	0.0074	Wholesale and retail trade	0.0041

Table 4 Top ten direct consumption coefficients in China's real estate sector, 2015-2017

2015		2017	
Sectors with top 10 coefficients	coefficients	Sectors with top 10 coefficients	coefficients
Finance	0.1041	Finance	0.1116
Leasing and Business Services	0.0522	Leasing and Business Services	0.0527
Real Estate	0.0452	Real Estate	0.0343
Construction	0.0229	Construction	0.0089
Transportation, storage and postal	0.0073	Information transmission, software and information technology services	0.0058
Accommodation and Catering	0.0056	Paper, printing and educational and sporting goods	0.0048
Paper, Printing and Educational and Sporting Goods	0.0055	Transportation, storage and postal	0.0046
Information transmission, software and information	0.0049	Electricity, heat production and supply	0.0043

technology services			
Food and tobacco	0.0047	Food and tobacco	0.0043
Wholesale and Retail	0.0044	Accommodation and catering	0.0042

Table 5 Top ten direct consumption coefficients in China's real estate sector, 2018-2020

2018		2020	
Sectors with top 10 coefficients	coefficients	Sectors with top 10 coefficients	coefficients
Finance	0.1118	Finance	0.1131
Leasing and Business Services	0.0537	Leasing and Business Services	0.0615
Real Estate	0.0334	Real Estate	0.0414
Construction	0.0126	Construction	0.0133
Information transmission, software and information technology services	0.0070	Information transmission, software and information technology services	0.0082
Paper, printing and educational and sporting goods	0.0048	Paper, printing and educational and sporting goods	0.0050
Transportation, storage and postal	0.0045	Food and tobacco	0.0044
Electricity, heat production and supply	0.0042	Production and supply of electricity and heat	0.0043
Food and tobacco	0.0042	Transportation, storage and postal	0.0040
Accommodation and catering	0.0041	Accommodation and catering	0.0039

In Tables 1-5, it can be seen that prior to 2012, the top three direct consumption coefficients of real estate on other sectors were finance, rental and business services, and construction. The real estate sector is in the top ten but is located relatively far back. From 2012 to 2020, the construction sector drops to fourth place, while the real estate sector rises to the third place.

The reason for this shift can be attributed to the policy regulation of the Chinese real estate market. By reviewing the real estate policies from 2012 to 2020, it can be seen that the Chinese government has been continuously promoting the construction of guaranteed housing projects, taking effective measures to increase the supply of commercial housing and promoting the parallel operation of public and low-cost housing, thus accelerating the de-stocking of the real estate market, hence there is a rapid increase in the number of products or services consumed by the real estate sector itself.

In order to intuitively reflect the production chain of the real estate sector, the complete consumption coefficient is calculated through the input-output table. When indirect physical consumption is taken into account, almost all sectors are production-related to the real estate sector. It can be seen from Table 6-10 that, among all sectors, the sectors of finance and insurance, non-metallic mineral products, construction, chemical sector, leasing and business services, metal smelting and rolling processing, electrical machinery and equipment manufacturing, communication equipment, computer and other electronic equipment manufacturing, electricity, heat production and supply, petroleum processing, coking and nuclear fuel processing, etc. have all been closely associated with the real estate sector over the years. The financial sector is still the most important intermediate input sector in the real estate sector. The dynamics of the complete consumption coefficients of each sector are similar to the trend of the direct consumption coefficients.

Table 6 Top ten Complete consumption coefficients in China's real estate sector, 1997-2002

1997		2002	
Sectors with top 10 coefficients	coefficients	Sectors with top 10 coefficients	coefficients
Non-metallic mineral products industry	0.0658	Finance and Insurance	0.0957
Finance and Insurance	0.0589	Leasing and Business Services	0.0465
Construction industry	0.0426	Construction	0.0445
Chemical Industry	0.0407	Metal smelting and rolling processing industry	0.0389
Social Service Industry	0.0354	Chemical Industry	0.0348
Metal smelting and rolling processing industry	0.0324	Transportation and Storage	0.0318
Commerce	0.0311	Communication and Electronic Equipment Manufacturing	0.0279
Machinery Industry	0.0235	Wholesale and retail trade	0.0264
Paper, printing and stationery manufacturing	0.0222	General and special equipment manufacturing	0.0260
Electrical machinery and equipment manufacturing	0.0658	Transportation equipment manufacturing	0.0230

Table 7 Top ten Complete consumption coefficients in China's real estate sector, 2005-2007

2005		2007	
Sectors with top 10 coefficients	coefficients	Sectors with top 10 coefficients	coefficients
Finance and Insurance	0.0612	Chemical Industry	0.0489
Leasing and business services	0.0478	Finance industry	0.0352
Metal smelting and rolling processing industry	0.0345	Metal smelting and rolling processing industry	0.0330
Chemical industry	0.0339	Leasing and business services	0.0287
Electricity, heat and power production and supply industry	0.0321	Electricity and heat production and supply industry	0.0251
Communication and other electronic equipment manufacturing	0.0313	Petroleum Coking and Nuclear Fuel Processing Industry	0.0233
Transportation and storage	0.0280	Communication and electronic equipment manufacturing	0.0202
Construction	0.0226	Electrical machinery and equipment manufacturing	0.0193
Accommodation and catering	0.0215	Accommodation and catering	0.0173
Non-metallic mineral products industry	0.0215	Transportation and storage	0.0167

Table 8 Top ten Complete consumption coefficients in China's real estate sector, 2010-2012

2010		2012	
Sectors with top 10 coefficients	coefficients	Sectors with top 10 coefficients	coefficients
Chemical Industry	0.0701	Finance	0.1332
Finance industry	0.0615	Leasing and Business Services	0.0635
Leasing and business services	0.0466	Real Estate	0.0444
Metal smelting and rolling processing industry	0.0383	Chemical Products	0.0312
Electricity and heat production and supply industry	0.0344	Construction	0.0280

Petroleum, coking and nuclear fuel processing industry	0.0340	Metal Smelting and Rolling Products	0.0261
Transportation and Storage	0.0299	Transportation, storage and postal services	0.0246
Accommodation and catering	0.0267	Paper, printing and stationery and sporting goods	0.0233
Electrical machinery and equipment manufacturing	0.0249	Production and supply of electricity and heat	0.0210
Food manufacturing and tobacco processing industry	0.0242	Wholesale and retail	0.0188

Table 9 Top ten Complete consumption coefficients in China's real estate sector, 2015-2017

2015		2017	
Sectors with top 10 coefficients	coefficients	Sectors with top 10 coefficients	coefficients
Finance	0.1392	Finance	0.1435
Leasing and Business Services	0.0808	Leasing and Business Services	0.0839
Real Estate	0.0595	Real Estate	0.0553
Chemical Products	0.0340	Transportation, storage and postal	0.0232
Transportation, warehousing and postal	0.0309	Paper, printing and educational and sporting goods	0.0228
Construction	0.0271	Chemical Products	0.0204
Food and Tobacco	0.0261	Food and tobacco	0.0188
Paper, printing and educational and sporting goods	0.0253	Wholesale and Retail	0.0168
Wholesale and Retail	0.0231	Accommodation and catering	0.0162
Metal smelting and rolling products	0.0228	Information, software and information technology services	0.0157

Table 10 Top ten Complete consumption coefficients in China's real estate sector, 2018-2020

2018	2020

Sectors with top 10 coefficients	coefficients	Sectors with top 10 coefficients	coefficients
Finance	0.1438	Finance	0.1450
Leasing and Business Services	0.0865	Leasing and Business Services	0.0934
Real Estate	0.0555	Real Estate	0.0629
Transportation, storage and postal	0.0242	Transportation, storage and postal	0.0225
Paper, printing and education and sporting goods	0.0221	Information, software and information technology services	0.0217
Information, software and information technology services	0.0200	Paper, printing and stationery and sporting goods	0.0215
Chemical products	0.0198	Wholesale and retail	0.0191
Wholesale and Retail	0.0182	Chemical products	0.0179
Food and tobacco	0.0176	Food and tobacco	0.0174
Accommodation and catering	0.0166	Construction	0.0153

B. Topology Analysis of the Input-Output Network

The complex network constructed with the input-output tables can visually display the production linkages between the real estate sector and other sectors, and observe the vertices in the network to analyze the strength of linkages and changes in the network topology between the real estate sector and other sectors. The specific network structure characteristic values are shown in Table 11.

Table 11 Overall structural characteristics of the input-output network by year

Time	Network density	Average path length	Network clustering coefficient
1997	0.924	1.053	0.921
2002	0.922	1.057	0.918
2005	0.926	1.052	0.924
2007	0.98	1.044	0.956
2010	0.976	1.049	0.951
2012	0.971	1.053	0.947
2015	0.974	1.05	0.95
2017	0.965	1.037	0.94

2018	0.965	1.037	0.94
2020	0.965	1.037	0.94

In this paper, networks are constructed using input-output tables for the period 1997-2020 during the observation period, and the vertices of each network are the sectors in the input-output tables, while the edge weights are the direct consumption coefficients. The three commonly used characteristic indicators of network density, average path length, and network clustering coefficient are given in Table 11. As can be seen from Table 11, the variance of the average path length in the sample interval is the smallest among the above three overall network indicators, indicating that the path lengths between sectors in the constructed input-output network show an overall fluctuation trend of relative stability; moreover, the mean value of the average path length of the network is 1.047, i.e., the maximum mutual impact between any two vertices can be reached by only 1.047 edges, indicating that that the spillover process of risk shocks is very rapid between any two sectors, which also provides the basis for a strong linkage of real estate risk in the network; furthermore, since 2017, it is found that the average path length of the network decreases and is smaller than the mean value in 2017, 2018 and 2020, and one vertex needs to pass through 1.037 vertices on average to reach the other vertices. It further illustrates the faster risk propagation under the current real estate cycle.

The network clustering coefficient is used to measure the degree of vertex aggregation. As can be seen from Table 11, the annual average of the network clustering coefficients is the largest in 2007. Firstly, the steeper network clustering coefficients indicate that the input-output networks among the sectors were tightly connected in this year and that each sector has significant production linkages with other sectors in the network. It can be assumed that the impact of the epidemic on the Chinese real estate market spilled over the inter-city real estate network very rapidly. Secondly, the elevated network aggregation coefficient indicates that a few vertices in the network hold more connected edges in the network. This is consistent with the increase in the number of degrees out of this vertex, Wuhan, in the network for the four quarters of 2020.

According to the network density, the average path length of the network and the network aggregation coefficient, the change pattern of these three network indicators is roughly the same as the trend of China's economic cycle. the Southern Talk of Deng Xiaoping in early 1992 initiated a new round of China's economic cycle. After the rapid economic growth, inflation also rose sharply, with CPI reaching 24.1% year-on-year in 1994. In order to curb inflation, policies started to contract and economic growth gradually went downward, then superimposed on the Southeast Asian financial crisis that started in the second half of 1997, China's economic growth rate reached the low point of this cycle. Therefore, the input-output network in 1997 was sparse and the vertices were less closely linked to each other.

The next economic cycle was roughly between 2000 and 2010, during which China's economy

began to grow rapidly around fixed asset investment in many areas of the real estate market, and heavy sectors such as coal, steel, construction, and chemicals led the economy into a new cycle. 2008's subprime mortgage crisis in the U.S. did not interrupt this cycle, and in 2010 the fiscal and monetary policy easing brought another round of investment boom, after which the economic cycle gradually declined. This is consistent with the closer linkages between the vertices in the input-output network in Table 11: as the economic environment evolves, production increases across sectors, strengthening inter-sector linkages.

The fourth economic cycle is roughly between 2011-2020, a period in which real estate and heavy chemical sectors continue to exit, but no new dominant sectors emerge, and economic growth shows a step-down from high growth of 11% to medium growth of 6% over a ten-year period. With each economic downturn, the government can only stabilize the economy by relaxing the real estate policy as no new leading sectors emerge. Therefore, the production linkage of the network also increases and then decreases with the fluctuation of the economic cycle during the period of 2012-2020.

4.3 Risk Contagion Analysis Based on the Input-Output Network

Figures 1-5 show the SPT network for the decade of 1997-2020, where the average path lengths of the network for each year are 1.9393, 1.8922, 2.2119, 2.2917, 1.9709, 2.4245, 2.0363, 2.1880, 2.1810 and 2.1239, respectively.

During the observation period, comparing with other years, the average path length is relatively short in 1997, 2002 and 2010, where the average path length is less than 2. This means that the distance between vertices is shorter, the production between vertices is more closely related and the transmission of risks in the network is faster. Comparing the average path length of the SPT network with the fluctuations of the Chinese real estate market, it is found that the real estate sector suffered negative shocks from external sources in 1997, 2002 and 2010: the Chinese real estate sector was hit by an economic downturn crisis in 1997. The Asian financial crisis broke out in 1997, and China's real estate sector was affected by the financial turmoil, with Hong Kong bearing the brunt of it, and the housing market cooled considerably, with a large number of "rotten buildings" appearing and China's real estate sector on the verge of collapse. In 2002, the Chinese government issued a document to tighten the regulation of land supply, housing structure and market, which slowed down the rise of housing prices. At the same time, the aftermath of the 1997 financial crisis was still affecting the real estate sector. And in 2010, China's real estate policy has shifted from the previous support to curbing speculation and curbing the excessive rise in house prices, and has adopted various regulation and control tools such as land, finance and taxation. This also shows that when the economic environment and policy regulation is unfavorable, the real estate sector and sectors closely associated with the real estate sector in production should take the initiative to adjust their own business strategies to prevent and control the spread of risks in a timely manner.

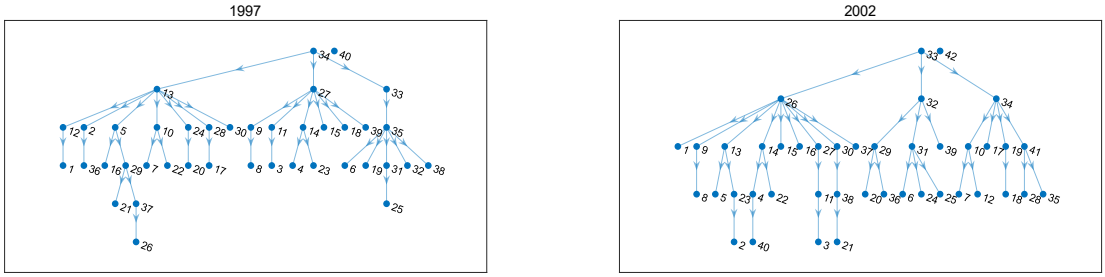

Figure 1 The SPT networks in 1997 and 2002

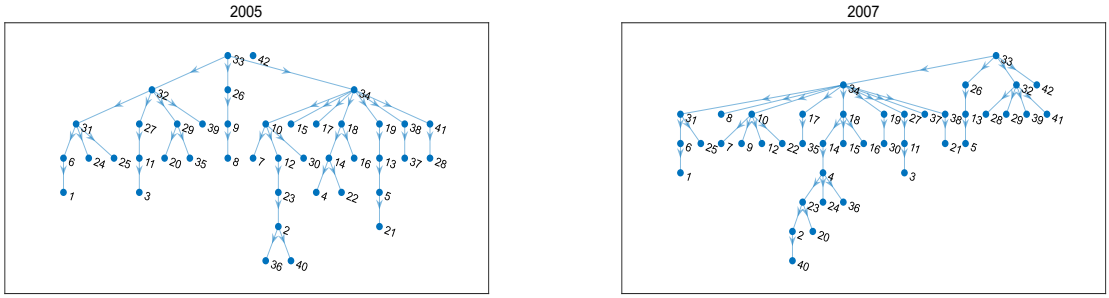

Figure 2 The SPT networks in 2005 and 2007

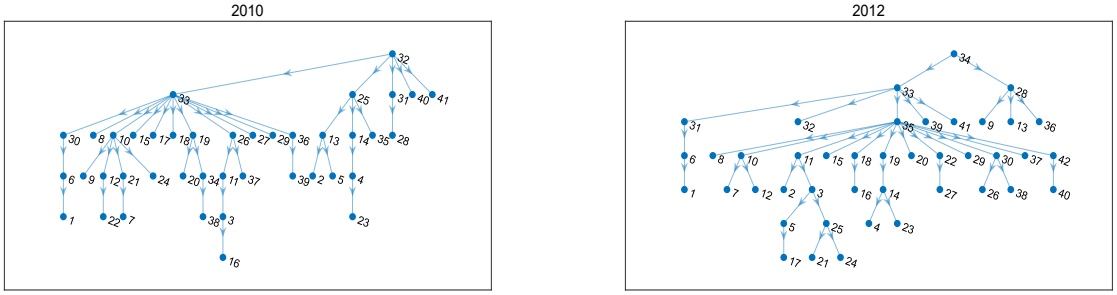

Figure 3 The SPT networks in 2010 and 2012

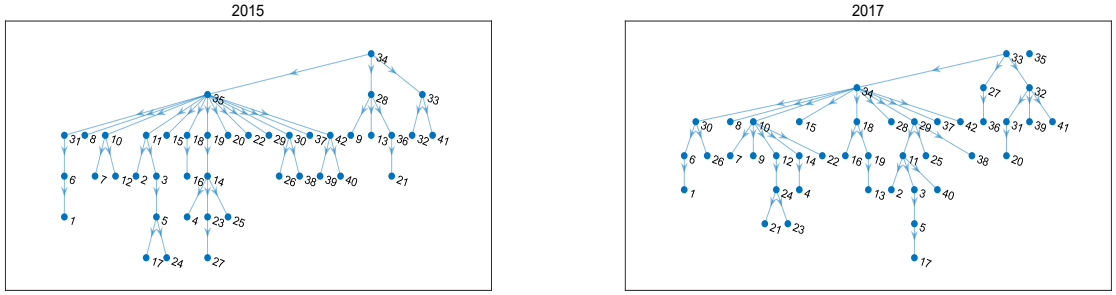

Figure 4 The SPT networks in 2015 and 2017

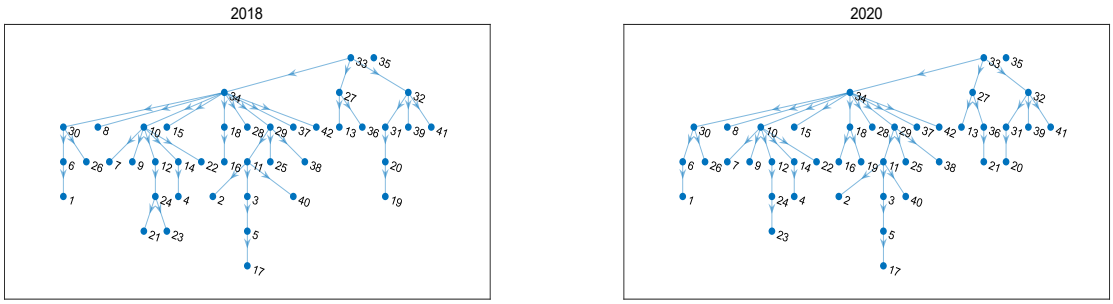

Figure 5 The SPT networks in 2017 and 2020

Combining Figures 1-5, when the real estate sector is assumed to be at risk and there is a risk spillover, with the real estate sector as the source vertex, comparing the SPT network for each year from 1997 to 2020, we can see that the real estate sector, the construction sector, the financial sector, and the leasing and commercial sector are always closely related to the real estate sector, except for 1997 when the real estate sector had a close production linkage with the non-metallic mineral products sector, when there is a risk spillover from the real estate sector. They are the first sectors to be affected by the spread of risks in the real estate sector along the production linkage. For non-metallic mineral products, construction, finance, and leasing and business services, these sectors are widely spread in the risk contagion chain.

At the same time, Figure 1-5 also shows that there are many sectors involved in the risk transmission chain of real estate sector, and that the sector of leasing and business services are the central vertex in the SPT network. This is because the leasing and business services sector involves many businesses, such as machinery and equipment operation and leasing, agricultural machinery operation and leasing, computer and communication equipment operation and leasing, other machinery and equipment operation and leasing, cultural and sports equipment and supplies leasing, other general management services, advertising, and public employment services. As a result, the sector is closely related to the computer and communication, agricultural, and cultural, sports and entertainment sectors, and has become an important vertex for spreading risks in the real estate sector.

V. Conclusion

As an important sector in the social economy, the real estate sector has a long production chain and is important in promoting urbanization and driving the development of related sectors. However, the sector characteristics of strong cyclicality and high gearing make it risky to a certain extent. Credit risk contagion is fissile and diffuse. In-depth discussion of credit risk and its contagion effect in the real estate sector is indispensable and crucial to stabilize the financial market order and contribute to the economic and social development of China.

The calculated direct consumption coefficient shows that the production linkage between the real

estate sector and other sectors strengthens with the relaxation of the economic environment and real estate policies, indicating that the development of the real estate sector is deeply affected by factors such as policy contraction and macroeconomic downturn. By comparing the top ten sectors in terms of complete consumption coefficient and direct consumption coefficient, the length of the production chain of the real estate sector can be seen more visually.

From the shortest path spanning tree network (SPT network) of each year, we can find that the path length of risk contagion is also related to the economic environment and real estate fluctuation cycle: the path of real estate risk contagion shortens with the downward trend of the economy and real estate market, indicating that the network of risk propagation is tighter and faster when the environment is more fragile; The sector at the central vertex in the SPT network not only has its own close production connection with the real estate sector, but also has a close downstream production sector of its own. For example, non-metallic mineral products are in the downstream of the construction sector, and the development of the construction sector needs to consume a large amount of products of non-metallic mineral products.

Based on the above conclusions, in the process of interactive development of the real estate sector and its related sectors, strengthening risk management in the real estate sector will not only help maintain the stable development of the real estate sector, but also ensure the smooth operation of the overall economy. As for the path of risk propagation, attention should be paid not only to the capital linkage between the real estate sector and other sectors, but also to the production linkage among them. Therefore, when preventing and controlling real estate risks, it is also necessary to prevent and control the contagion of its risks on the input-output network, identify the path of risk contagion in a timely manner, and help the central vertices on the path to isolate the risks. In addition, when formulating prevention and control policies according to the path of risk transmission, it is also necessary to make dynamic adjustments according to the stage of economic development to ensure the smoothness of the industrial chain.

References

1. Anagnostou I, Sourabh S, Kandhai D. Incorporating contagion in portfolio credit risk models using network theory. Complexity, 2018(3): 1–15.
2. Chan S，Han G F，Zhang W L. How strong are the linkages between real estate and other sectors in China? [J]. Research in International Business and Finance，2016, 36: 52-72.
3. Chen T Q, He J M, Li X D. An evolving network model of credit risk contagion in the financial market. Technological & Economic Development of Economy, 2017, 23(1): 22–37.
4. Chiang S H，Chen C F. From systematic to systemic risk among G7 members: Do the stock

or real estate markets matter? [J]. Journal of International Financial Markets Institutions & Money，2022，79.

5. Damianov D S，Elsayed A H. On the transmission of spillover risks between the housing market，the mortgage and equity REITs markets，and the stock market[J]. Finance Research Letters，2018，27: 193-200.
6. Li B，Li C H，Wang L. Does the shareholding network affect bank's risk-taking behavior? An exploratory study on Chinese commercial banks[J]. Finance Research Letters， 2019，31: 334-348.
7. Pais A，Stork P A. Bank Size and Systemic Risk[J]. European Financial Management， 2013，19(3): 429-451.
8. Xu Q，Yan H，Zhao T. Contagion effect of systemic risk among industry sectors in China’s stock market[J]. The North American Journal of Economics and Finance， 2022，59: 101576.
9. Cao J, Lei LH. A study on risk spillover between financial industry and real estate industry based on generalized CoES approach [J]. Operations Research and Management, 2021, 30(04):200-205. In Chinese.
10. Chen Shaoling, Tan Liming, Yang Haisheng, Cui Jie. A study on the systemic importance of China's financial sector - a complex network analysis based on HD-TVP-VAR model [J]. Systems Engineering Theory and Practice, 2021, 41(08):1911-1925. In Chinese.
11. Fang Y, Chen M, Nancy P. Yang. Research on the spillover effect of financial market on systemic risk in banking industry and channel identification[J]. Nankai Economic Research, 2018(05): 58-75. In Chinese.
12. Gong Xiaoli, Xiong Xiong. A study on financial risk contagion from the perspective of volatility spillover network[J]. Financial Research, 2020(05):39-58. In Chinese.
13. Liu Chao, Xu Junhui, Zhou Wenwen. Research on risk spillover effects in Chinese financial markets - based on spillover index and complex network approach [J]. Systems Engineering Theory and Practice, 2017, 37(04):831-842. In Chinese.
14. Liu Chao, Hao Danhui, Tang Xiaowen, Liu Chenqi. Research on the cross-market transmission mechanism of financial risk based on complex networks - taking data from the financial crisis period (2007 - 2009) as an example[J]. Operations Research and Management, 2018, 27(08):155-161+181. In Chinese.

15. Long Jianyou, Ling Yuxiu, Xie Chi. Research on credit risk contagion in real estate industry based on complex network theory [J]. Journal of Systems Engineering, 2022, 37(03):289-302. In Chinese.
16. Wang Guojun, Liu Shuixing. Research on the driving effect of real estate industry on related industries[J]. Economic Research,2004(08):38-47. In Chinese.
17. Zhang Jinlin,Sun Lingyun. Research on the mechanism and path of cross-market financial risk contagion under complex network theory[J]. Journal of Zhongnan University of Economics and Law, 2020(02):110-121. In Chinese.

Appendix

Table 1 Comparison table of node serial number and production department, 1997-2010

1997		2002		2005		2007		2010	
1	Agriculture	1	Agriculture, forestry and fishery	1	Agriculture	1	Agriculture, forestry and fishery	1	Agriculture, forestry and fishery
2	Coal Mining	2	Coal mining and washing industry	2	Coal mining and washing industry	2	Coal mining and washing industry	2	Coal mining and washing industry
3	Oil and gas mining	3	Oil and gas mining industry	3	Oil and gas mining industry	3	Oil and gas mining industry	3	Oil and gas mining industry
4	Metal mining industry	4	Metal mining industry	4	Metal mining industry	4	Metal mining and processing industry	4	Metal mining and processing industry
5	Non-metallic mining industry	5	Non-metallic mining industry	5	Non-metallic mining industry	5	Non-metallic mining and other mining industry	5	Non-metallic mining and other mining industry
6	Food manufacturing and tobacco	6	Food manufacturing and tobacco	6	Food manufacturing and tobacco	6	Food manufacturing and tobacco	6	Food manufacturing and tobacco

	processing industry		processing industry		processing industry		processing industry		processing industry
7	Textile industry	7	Textile industry	7	Textile industry	7	Textile industry	7	Textile industry
8	Clothing, leather, down and other fiber products manufacturing	8	Clothing, leather and down products industry	8	Clothing, leather and down products industry	8	Textile, clothing, shoes, hats, leather and down products industry	8	Textile, clothing, shoes, hats, leather and down products industry
9	Wood processing and furniture manufacturing	9	Wood processing and furniture manufacturing	9	Wood processing and furniture manufacturing	9	Wood processing and furniture manufacturing	9	Wood processing and furniture manufacturing
10	Paper printing and stationery manufacturing	10	Paper printing and stationery manufacturing	10	Paper printing and stationery manufacturing	10	Paper, printing and sporting goods manufacturing	10	Paper, printing and sporting goods manufacturing
11	Petroleum processing and coking industry	11	Petroleum processing, coking and nuclear fuel processing industry	11	Petroleum processing, coking and nuclear fuel processing industry	11	Petroleum processing, coking and nuclear fuel processing industry	11	Petroleum processing, coking and nuclear fuel processing industry
12	Chemical industry	12	Chemical industry	12	Chemical industry	12	Chemical industry	12	Chemical industry
13	Non-metallic mineral products industry	13	Non-metallic mineral products industry	13	Non-metallic mineral products industry	13	Non-metallic mineral products industry	13	Non-metallic mineral products industry
14	Metal smelting	14	Metal smelting	14	Metal smelting	14	Metal smelting	14	Metal smelting

	and rolling processing industry		and rolling processing industry		and rolling processing industry		and rolling processing industry		and rolling processing industry
15	Metal products industry	15	Metal products industry	15	Metal products industry	15	Metal products industry	15	Metal products industry
16	Machinery industry	16	General and special equipment manufacturing	16	General and special equipment manufacturing	16	General and special equipment manufacturing	16	General and special equipment manufacturing
17	Transportation equipment manufacturing	17	Transportation equipment manufacturing	17	Transportation equipment manufacturing	17	Transportation equipment manufacturing	17	Transportation equipment manufacturing
18	Electrical machinery and equipment manufacturing	18	Electrical, mechanical and equipment manufacturing	18	Electrical, mechanical and equipment manufacturing	18	Electrical machinery and equipment manufacturing	18	Electrical machinery and equipment manufacturing
19	Electronics and communications equipment manufacturing	19	Communications equipment, computers and other electronic equipment manufacturing	19	Communications equipment, computers and other electronic equipment manufacturing	19	Communications equipment, computers and other electronic equipment manufacturing	19	Communications equipment, computers and other electronic equipment manufacturing
20	Instrument and cultural office machinery manufacturing	20	Instrumentation and cultural office machinery manufacturing	20	Instrumentation and cultural office machinery manufacturing	20	Instrumentation and cultural office machinery manufacturing	20	Instrumentation and cultural office machinery manufacturing
21	Machinery and equipment repair industry	21	Other manufacturing industries	21	Other manufacturing industries	21	Crafts and other manufacturing industries	21	Crafts and other manufacturing industries

									(including scrap waste)
22	Other manufacturing industries	22	Scrap and waste	22	Scrap and waste	22	Scrap and waste	22	Electricity, heat production and supply industry
23	Scrap and waste	23	Electricity, heat production and supply industry	23	Electricity, heat production and supply industry	23	Electricity, heat production and supply industry	23	Gas production and supply industry
24	Electricity and steam hot water production and supply industry	24	Gas production and supply industry	24	Gas production and supply industry	24	Gas production and supply industry	24	Water production and supply industry
25	Gas production and supply industry	25	Water production and supply industry	25	Water production and supply industry	25	Water production and supply industry	25	Construction
26	Water production and supply industry	26	Construction	26	Construction	26	Construction	26	Transportation and storage industry
27	Construction	27	Transportation and storage industry	27	Transportation and storage industry	27	Transportation and storage industry	27	Postal industry
28	Freight transportation and storage	28	Postal industry	28	Postal industry	28	Postal industry	28	Information transmission, computer services and software
29	Post and Telecommunications	29	Information transmission, computer	29	Information transmission, computer	29	Information transmission, computer	29	Wholesale and retail trade

			services and software		services and software		services and software		
30	Commerce	30	Wholesale and retail trade	30	Wholesale and retail trade	30	Wholesale and retail trade	30	Accommodation and Catering
31	Catering	31	Accommodation and catering	31	Accommodation and catering	31	Accommodation and Catering	31	Finance
32	Passenger transportation	32	Finance and Insurance	32	Finance and Insurance	32	Finance	32	Real estate
33	Finance and Insurance	33	Real estate	33	Real estate	33	Real estate	33	Rental and business services
34	Real Estate	34	Rental and business services	34	Rental and business services	34	Rental and business services	34	Research and Experimental Development
35	Social Services	35	Tourism	35	Scientific Research	35	Research and Experimental Development	35	Comprehensive technical services
36	Health, Sports and Social Welfare	36	Scientific Research	36	Comprehensive technical services	36	Comprehensive technical services	36	Water, Environment and Public Facilities Management
37	Education, Culture, Arts, Radio, Film and Television	37	Comprehensive technical services	37	Water, environment and public facilities management	37	Water, Environment and Public Facilities Management	37	Residential Services and Other Services
38	Science and Research	38	Other Social Services	38	Residential Services and	38	Residential Services and	38	Education

					Other Services		Other Services		
39	Comprehensive technical services	39	Education	39	Education	39	Education	39	Health, social security and social welfare
40	Administration and other industries	40	Health, social security and social welfare	40	Health, social security and social welfare	40	Health, social security and social welfare	40	Culture, sports and entertainment
		41	Culture, Sports and Entertainment	41	Culture, sports and entertainment	41	Culture, sports and entertainment	41	Public administration and social organizations
		42	Public administration and social organizations	42	Public administration and social organizations	42	Public administration and social organizations		

Table 2 Comparison table of node serial number and production department, 2012-2020

2012		2015		2017		2018		2020	
1	Agriculture, forestry and fishery products and services	1	Agriculture, forestry and fishery products and services	1	Agriculture, forestry and fishery products and services	1	Agriculture, forestry and fishery products and services	1	Agriculture, forestry and fishery products and services
2	Coal mining products	2	Coal mining products	2	Coal mining products	2	Coal mining products	2	Coal mining products
3	Oil and gas mining products	3	Oil and gas mining products	3	Oil and gas mining products	3	Oil and gas mining products	3	Oil and gas mining products
4	Metal Mining Products	4	Metal Mining Products	4	Metal Mining Products	4	Metal Mining Products	4	Metal Mining Products

5	Non-metallic and other mineral extraction products	5	Non-metallic and other mineral extraction products	5	Non-metallic and other mineral extraction products	5	Non-metallic and other mineral extraction products	5	Non-metallic and other mineral extraction products
6	Food and tobacco	6	Food and tobacco	6	Food and tobacco	6	Food and tobacco	6	Food and tobacco
7	Textiles	7	Textiles	7	Textiles	7	Textiles	7	Textiles
8	Textile, clothing, shoes, hats, leather and down and their products	8	Textile, clothing, shoes, hats, leather and down and their products	8	Textile, clothing, shoes, hats, leather and down and their products	8	Textile, clothing, shoes, hats, leather and down and their products	8	Textile, clothing, shoes, hats, leather and down and their products
9	Woodworking products and furniture	9	Woodworking products and furniture	9	Woodworking products and furniture	9	Woodworking products and furniture	9	Woodworking products and furniture
10	Paper printing and stationery and sporting goods	10	Paper printing and stationery and sporting goods	10	Paper printing and stationery and sporting goods	10	Paper printing and stationery and sporting goods	10	Paper printing and stationery and sporting goods
11	Petroleum, coking products and processed nuclear fuel products	11	Petroleum, coking products and processed nuclear fuel products	11	Petroleum, coking products and processed nuclear fuel products	11	Petroleum, coking products and processed nuclear fuel products	11	Petroleum, coking products and processed nuclear fuel products
12	Chemical products	12	Chemical products	12	Chemical products	12	Chemical products	12	Chemical products
13	Non-metallic	13	Non-metallic	13	Non-metallic	13	Non-metallic	13	Non-metallic

	mineral products		mineral products		mineral products		mineral products		mineral products
14	Metal Smelting and Rolling Products	14	Metal Smelting and Rolling Products	14	Metal Smelting and Rolling Products	14	Metal Smelting and Rolling Products	14	Metal Smelting and Rolling Products
15	Metal products	15	Metal products	15	Metal products	15	Metal products	15	Metal products
16	General equipment	16	General equipment	16	General equipment	16	General equipment	16	General equipment
17	Special equipment	17	Special equipment	17	Special equipment	17	Special equipment	17	Special equipment
18	Transportation equipment	18	Transportation equipment	18	Transportation equipment	18	Transportation equipment	18	Transportation equipment
19	Electrical machinery and equipment	19	Electrical machinery and equipment	19	Electrical machinery and equipment	19	Electrical machinery and equipment	19	Electrical machinery and equipment
20	Communication equipment, computers and other electronic equipment	20	Communicatio n equipment, computers and other electronic equipment	20	Communication equipment, computers and other electronic equipment	20	Communicatio n equipment, computers and other electronic equipment	20	Communication equipment, computers and other electronic equipment
21	Instruments and meters	21	Instruments and meters	21	Instruments and meters	21	Instruments and meters	21	Instruments and meters
22	Other manufacturing products	22	Other manufacturing products	22	Other manufacturing products and scrap waste	22	Other manufacturing products and scrap waste	22	Other manufacturing products and scrap waste
23	Scrap and waste	23	Scrap and waste	23	Metal products, machinery and equipment	23	Metal products, machinery and equipment	23	Metal products, machinery and equipment repair

					repair services		repair services		services
24	Metal products, machinery and equipment repair services	24	Metal products, machinery and equipment repair services	24	Electricity, heat production and supply	24	Electricity, heat production and supply	24	Electricity, heat production and supply
25	Electricity, heat production and supply	25	Electricity, heat production and supply	25	Gas production and supply	25	Gas production and supply	25	Gas production and supply
26	Gas production and supply	26	Gas production and supply	26	Water production and supply	26	Water production and supply	26	Water production and supply
27	Water production and supply	27	Water production and supply	27	Construction	27	Construction	27	Construction
28	Construction	28	Construction	28	Wholesale and retail	28	Wholesale and retail	28	Wholesale and retail
29	Wholesale and retail	29	Wholesale and retail	29	Transportation, storage and postal	29	Transportation, storage and postal	29	Transportation, storage and postal
30	Transportation, storage and postal	30	Transportation, storage and postal	30	Accommodation and catering	30	Accommodation and catering	30	Accommodation and catering
31	Accommodation and catering	31	Accommodation and catering	31	Information transmission, software and information technology services	31	Information transmission, software and information technology services	31	Information transmission, software and information technology services
32	Information	32	Information	32	Finance	32	Finance	32	Finance

	transmission, software and information technology services		transmission, software and information technology services						
33	Finance	33	Finance	33	Real Estate	33	Real Estate	33	Real Estate
34	Real Estate	34	Real Estate	34	Leasing and business services	34	Leasing and business services	34	Leasing and business services
35	Leasing and business services	35	Leasing and business services	35	Research and Experimental Development	35	Research and Experimental Development	35	Research and Experimental Development
36	Scientific research and technical services	36	Scientific research and technical services	36	Integrated Technology Services	36	Integrated Technology Services	36	Integrated Technology Services
37	Water, environment and public facilities management	37	Water, environment and public facilities management	37	Water, environment and public facilities management	37	Water, environment and public facilities management	37	Water, environment and public facilities management
38	Residential services, repair and other services	38	Residential services, repair and other services	38	Residential services, repair and other services	38	Residential services, repair and other services	38	Residential services, repair and other services
39	Education	39	Education	39	Education	39	Education	39	Education
40	Health and social work	40	Health and social work	40	Health and social work	40	Health and social work	40	Health and social work
41	Culture, sports	41	Culture, sports	41	Culture, sports	41	Culture, sports	41	Culture, sports

	and recreation		and recreation		and recreation		and recreation		and recreation
42	Public administration, social security and social organizations	42	Public administration, social security and social organizations	42	Public administration, social security and social organizations	42	Public administration, social security and social organizations	42	Public administration, social security and social organizations