United States International Trade Commission
Journal of International Commerce and Economics

On the Value Chain and International Specialization of China's Pharmaceutical Industry

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Abstract

This article studies the characteristics of the global pharmaceutical industry value chain and China's position in it, using the tools of value chain analysis, the Grubel & Lloyd (GL) index, and an input-output model. Research shows that in the global pharmaceutical value chain, proprietary medicine's value chain belongs completely to the producer-driven type, and the core added value is mainly from the input of research and development (R&D). Meanwhile, in the nonproprietary medicine value chain, raw medicine is comparatively independent and has a weak relation with the R&D stage. Based on the aforementioned findings, we conduct a concrete study of China's position in the global pharmaceutical

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industry value chain. The results of the study show that China now mainly produces nonproprietary medicine and stands at the lowest point of the "smile curve." Based on this, we calculate the Vertical Specialization (VS) Index, and analyze China's position in the R&D stage of the world pharmaceutical value chain. We conclude that China's cheaper labor cost is the main reason why multinational companies move their clinical trials to China.

I. Preface

Since China entered the World Trade Organization, the Chinese pharmaceutical industry has experienced rapid progress. By 2008, the foreign trade volume of the Chinese pharmaceutical industry had reached $12.28 billion, almost 2.6 times the volume in 2002. The global pharmaceutical industry plays a very important role in maintaining healthy and rapid development of China's pharmaceutical industry. Therefore, it is important to use modern value chain theory and international specialization theory to analyze the Chinese position in the global pharmaceutical industry's value chain.

This article studies the Chinese pharmaceutical industry and China's international specialization in the world value chain. The article is divided into six parts: part 2 is a literature review, describing previous research and methodologies related to those used in this article; part 3 focuses on the characteristics of the pharmaceutical industry value chain; part 4 is empirical research on international specialization within the world pharmaceutical industry; part 5 is an empirical study of the position of the Chinese pharmaceutical industry in the global chain, i.e., China's international specialization within the industry; and part 6 contains conclusions.

II. Review of Previous Research

Research on the theory of the value chain

The value chain concept was first put forward by Michael E. Porter in 1985. He deconstructed production as a series of value creation "links"; thus the connection of these "links" is called a value chain. Porter concluded that most value chains share similar characteristics and contain both production and supporting links. The former mainly includes production and marketing links, while the latter mainly includes related supporting links, such as construction, research and development (R&D), human resources, etc.

Gereffi (1999) divided value chains into producer-driven and buyer-driven from the perspective of product characteristics. Kaplinsky and Morris (2000) further divided value chains into simple value chains and extended value chains. They pointed out that most value chains can be reduced to four interrelated links: R&D, production, sales, and consumption. The detailed value chain is much more complicated than the one mentioned above. It is normally related to several lines of business or industry, and thus forms a bigger value chain network. Gereffi (2005) put forward the world value chain concept, including the entire R&D design link of the upper stage, the spare parts manufacture and assembly found in the middle stage, and the sales, branding, and service found in the lower stage in the world production network. This provided a new perspective for analyzing every country's international specialization within the global chain.

Research on international specialization

The earliest conception of international specialization can be traced back to Adam Smith's Absolute Advantage Theory, David Ricardo's Relative Advantage Theory, and Heckscher and Ohlin's Resource Endowment Theory. Since the latter part of the last century, intra-industry trade has gradually increased and became a part of main stream trade theory. Verdoom (1960) first put forward the phenomenon of increased trade in the same standard international trade classification (SITC) product group. Balassa (1963) also provided European evidence of the same phenomenon. Gray (1979) and Krugman (1981) developed theoretical models of intra-industry trade. Grubel & Lloyd (1975) also put forward the concept of dividing intra-industry trade into horizontal and vertical trade, a convention that most scholars have adopted.

In recent years, as multinational companies produce via various value chain links worldwide, vertical specialization is becoming the new type of intra-industry division. Vertical specialization refers to international specialization in different production stages in the same industry. This can be carried out not only by multinational companies but also by nonrelated companies whose markets are in different countries. The vertical specialization (VS) index proposed by Hummels, Ishii, and Yi (2001) provided a method of measuring vertical specialization. Since then, many scholars have conducted deep research and measurement of every country's vertical specification status. This theory shares the same theoretical base as the world value chain and will gradually become one of the mainstream theories of international specialization.

Research on China's overall value chain and international specialization

Until now, many scholars have studied the value chain and international specialization of China's overall industry or an individual industry. Liu and Chen (2007) measured the domestic total value added (TVA) in Chinese exports in 41 sectors, using a noncompetitive input-output table. A research team led by Ping (2005) calculated the VS index for trade between China and the United States. However, an input-output table that includes 123 sectors is required to analyze the pharmaceutical industry, so there has not been research on the TVA and VS indices of the pharmaceutical industry until now.

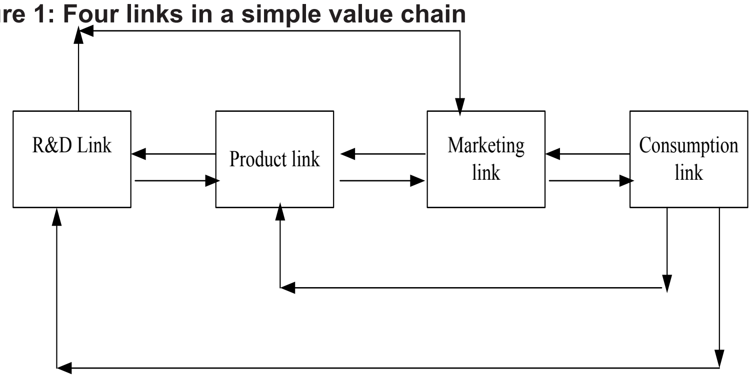
III. Study of the pharmaceutical industry value chain structure

Characteristics of the pharmaceutical industry value chain

Kaplinsky and Morris (2000) studied value chain structure and concluded that value chains can be classified as simple or extended. They maintained that most value chains can be described by the four-link model: R&D, production, sales, and consumption. However, the extended value chains of different products are more complicated. Kaplinsky and Morris used the timber industry as an example to illustrate an extended value chain link chart.

According to an investigation of six medical companies, including Jin Ling Medical Company in Jiangsu Province, and a medicine production link on the Web sites of Roche Company and Pfizer Incorporated, the simple value chain of medicine is similar to that of other finished products and follows Kaplinsky's model (2000), as illustrated in figure 1.

Figure 1: Four links in a simple value chain



However, the extended value chain of medicine has some noticeable particularities. First, there exist clear differences among the value chains of different medicines. There are various catalogues of medicines worldwide, such as proprietary medicine and nonproprietary medicine, which are divided by standards of intellectual protection. Though the above medicines are all final products, their production links' divisions show visible differences. In the automobile and IT industries, on the other hand, the production links of different types of final products share many similarities.

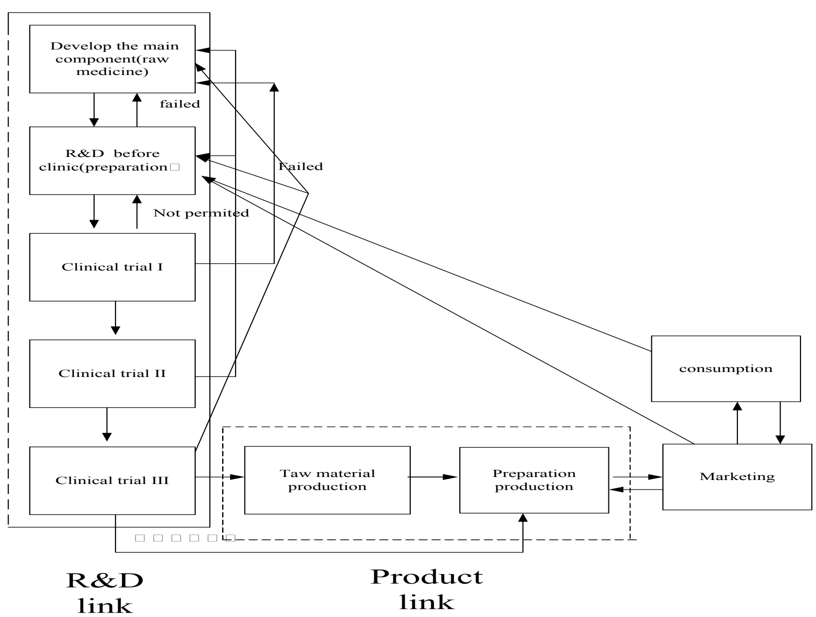
Second, the degree of modularization in medicine's value chain is relatively low. Currently, there are two modules in the production link of medicine's value chain: raw medicine production and preparation production. The former is a chemical link, while the latter is a physical link. Third, the R&D link of the medicine industry is more complicated, and the degree of modularization is comparatively high. According to Pfizer, the R&D link of one proprietary medicine will include many links; for example, finding the ingredients, clinical trial development, multiple phases of clinical trials, etc. Even after many years of clinical trials, a new medicine will not be sold on the market if it has not undergone a sufficient number of trials.

There are distinct characteristics in different R&D links in the pharmaceutical industry, of which the clinical trial is the most representative. In the above link, the clinical trial is the core link in the pharmaceutical industry and is also a particularly special link. The main function of this link is to transfer the trial medicines from the former R&D links into the human body, according to certain rules, and give feedback to the former R&D link. Therefore, this link requires not only high-tech talent, but also a large number of patients to participate in the trial, which greatly increases the cost of the entire R&D link.

Study of the extended value chain of proprietary medicine and nonproprietary medicine

The extended value chains of proprietary medicine and nonproprietary medicine are different. Figure 2 shows the extended value chain of proprietary medicine production. There is a long section of R&D links in proprietary medicine, which are indispensable for the follow-up link. Proprietary medicine production thus has high risk, high R&D input requirements, and high value added. According to PHRMA, in 2006, the R&D input of every proprietary medicine was about $1.3 billion. Because only large firms can afford such a high level of investment in R&D, the R&D and production links of proprietary medicine tend to be monopolized by multinational companies.

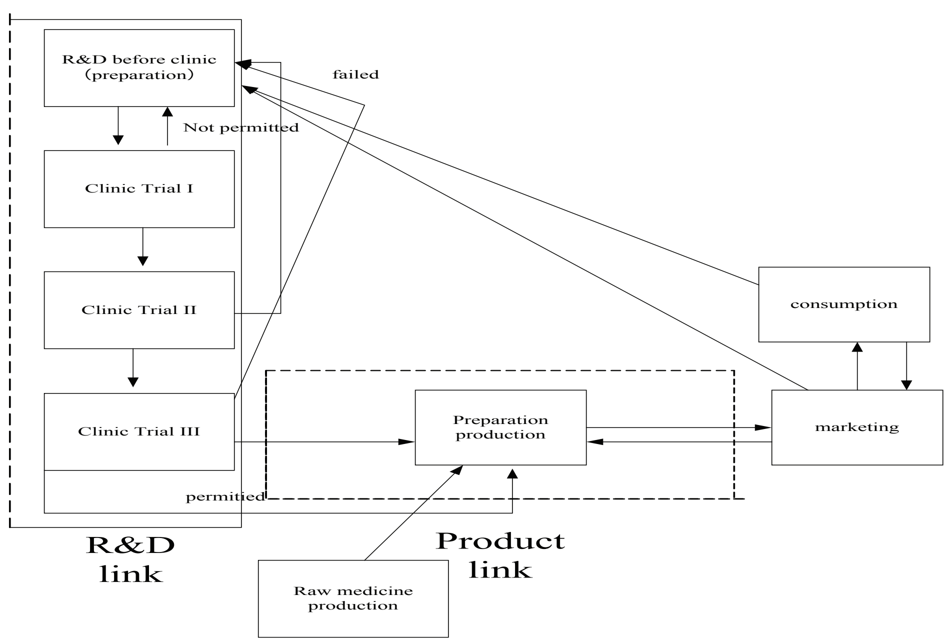
Figure 2: The extended value chain of proprietary medicine



Based on the above analysis, we draw some conclusions about the added value of various value chains of proprietary medicine. First, the R&D link is the link contributing the most added value in the proprietary medicine value chain. This can ensure the monopoly status of patent owners in the production. Second, the first two sublinks in the R&D link are the main value-added link, while the clinical trials are only an assistant link that provides data support to the first two links. Third, the production link is actually an auxiliary link to the R&D link, and exists to realize profits. Finally, due to an almost complete monopoly of multinational companies, the added value from the marketing link is far lower than that from the R&D link.

Figure 3 shows the extended value chain of nonproprietary medicine. A comparison of figures 2 and 3 reveals the following differences. First, the total value-added ratio of nonproprietary medicine is clearly lower than that of proprietary medicine. This is because nonproprietary medicine has no link of finding components, whereas for proprietary medicine, this link is located on the upper left of the "smile curve," and that is the maximum value-added link. Thus the value-added ratio of nonproprietary medicine is clearly lower than that of proprietary medicine.

Figure 3: The extended value chain of nonproprietary medicine



Second, nonproprietary medicine production is the link that is called "R&D before the clinical trial" and is also the main source of value-added in the chain. Figure 3 shows that raw medicine production for nonproprietary medicine is outside of the main value chain, and has no clear relation with the former R&D link, while the nonproprietary medicine pharmaceutical production has a direct connection with the R&D link. In fact, some nonproprietary medicine's pharmaceutical formulation is the same as that of the proprietary medicine, so there is no second sub-link of the R&D link in their value chain.

Third, there is more competition in the nonproprietary medicine market than in the proprietary medicine market, thus adding more value to the marketing link. Due to the lower barriers to entry in nonproprietary medicine (relative to proprietary medicine), nonproprietary medicine production is done by many companies in developed countries, and some small and medium-sized pharmaceutical manufacturers in developing countries. Thus, a greater degree of competition exists than in proprietary medicine. This kind of market structure increases the added value of the marketing link.

Finally, the degree of competition in nonproprietary medicine raw materials production is the highest. For most medicines, the difficulty in producing these raw materials is the production technology. If the production technology is public, the difficulty of producing raw materials for nonproprietary medicine is far lower than that of manufacture of nonproprietary manufactured medicine. Because raw materials produced by many corporations are highly substitutable, the share of value-added attributable to the raw materials production link is the lowest, and the degree of price competition is high.

Based on the above, this article makes a judgment on the characteristics of the value chains of proprietary medicine and nonproprietary medicine, according to Gereffi's method (1999). Gereffi holds that value chain can be judged by the system in table 1.

Table 1: Producer-driven and buyer-driven value chains

	Producer-Driven Commodity Chains	Buyer-Driven Commodity Chains
Drivers of Global Commodity Chains	Industrial Capital	Commercial Capital
Core Competencies	R&D; Production	Marketing; Design
Barriers	Economies of Scale	Economies of Scope
Typical Industries	Automobiles; Computers; Aircraft	Apparel; Footwear; Toys
Ownership of Manufacturing Firms	Transnational Firms	Local Firms, predominantly in developing countries
Main Network Links	Investment-based	Trade-based

Source: Gereffi, 1999b.

Using the above analysis, we can draw several conclusions regarding the value chains of proprietary medicine, nonproprietary medicine raw materials and nonproprietary manufactured medicine. Proprietary medicine's core competitive edge is mainly in R&D; it has high investment and technical input requirements, and is mainly produced by multinational companies. Therefore, it belongs to the producer-driven value chain. In nonproprietary manufactured medicine, sales links and production links are both important core competencies, and both multinational companies and local middle- and small-sized companies are involved in production. Thus, nonproprietary manufactured medicine shares characteristics of both producer-driven and buyer-driven value chains. The profit of nonproprietary medicine raw materials mainly comes from the sales link. Given the low barriers to entry, local small companies are the main producers of this kind of medicine. Thus, this value chain would be classified as a buyer-driven.

Analysis of the nature of three Chinese sub-pharmaceutical industries' value chains

The Chinese pharmaceutical industry has three sub pharmaceutical industries: the chemical medicine industry, the TCM industry, and the biological products industry. The value chain of the chemical medicine industry is very similar to the value chain above. The value chain of the TCM industry is a little different from the others.

The TCM industry (figure 4) has both consumer-driven and producer-driven value chain characteristics. Because sliced pieces of TCM can be produced without R&D, sales have an important status in the value chain of sliced pieces of TCM; thus, the value chain of sliced pieces is consumer-driven. The TCM product has both consumer-driven and producer-driven value chain characteristics.

Because of cultural differences and other reasons, currently, TCM has wide acceptance only in China and in the Chinese communities in East Asia, Southeast Asia, and some parts of South Asia. Europe and the United States, the major global markets of medicine, seldom accept TCM. As a result, TCM is not produced in a global supply chain. The value chains of TCM only exist within China's market and in the Chinese economic communities in Asia.

The value chain of biological products is also different from that of TCM. The raw material production link is the first link in the value chain and contributes the least added value. Almost no individual raw medicine research takes place in China, because the cost of R&D is very high. China's industry is mainly specialized in raw material production, and is essentially not competitive in the R&D link or the preparation link.

Analysis of the characteristics of the Chinese pharmaceutical industry value chain

The Chinese pharmaceutical industry has two important characteristics. First, the industry has a high degree of dispersion; no multinational company exists. According to the Chinese High-Tech Statistics Yearbook, the share of value-added attributable to Chinese multinational companies was 22.3 percent in 2007. According to a new U.S.-created pharmaceutical committee, the sales volume of the 30 largest multinational companies makes up to 76.9 percent of total pharmaceutical sales in the United States. This shows that the Chinese pharmaceutical industry is actually led by small and medium-sized companies, not multinationals.

Second, the Chinese pharmaceutical industry does not contribute much to the R&D link. Chinese R&D spending in the industry is low. The Chinese input of science activities in the pharmaceutical industry was only 6.3 billion yuan in 2007. In contrast, the Pfizer company spent $8.7 billion on R&D in 2008. In addition, the Chinese pharmaceutical industry's R&D intensity is low. The following table shows the differences in R&D intensity between China and developed countries in pharmaceutical manufacturing.

Figure 4: Value chain of Traditional Chinese Medicine (TCM)

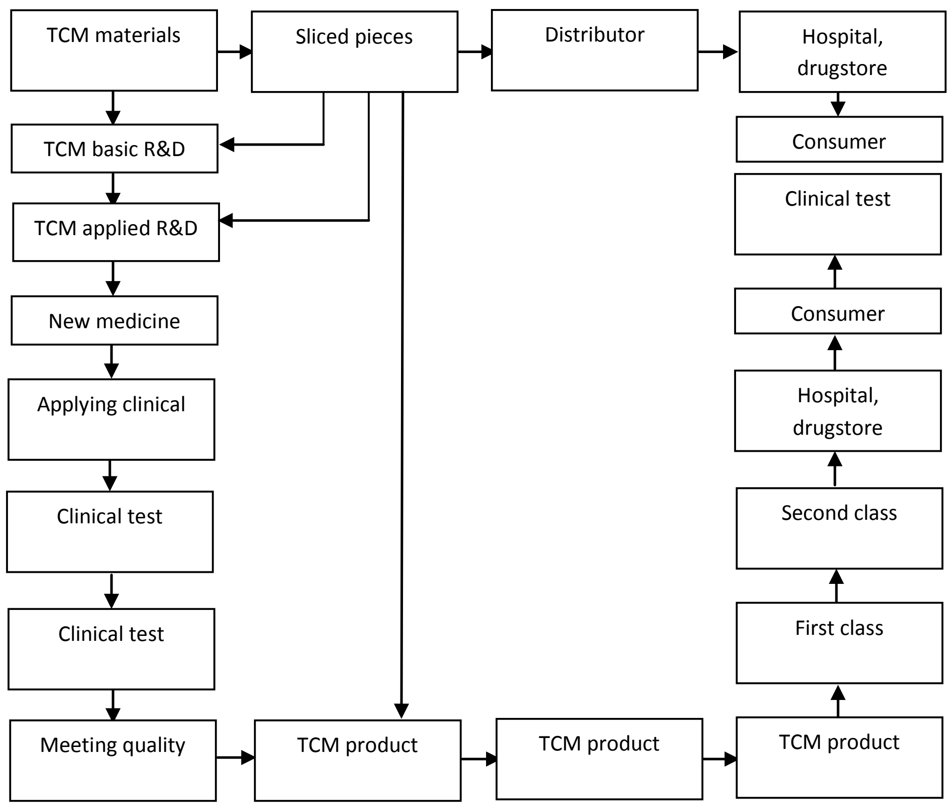


Figure 5: Value chain of Biological Products

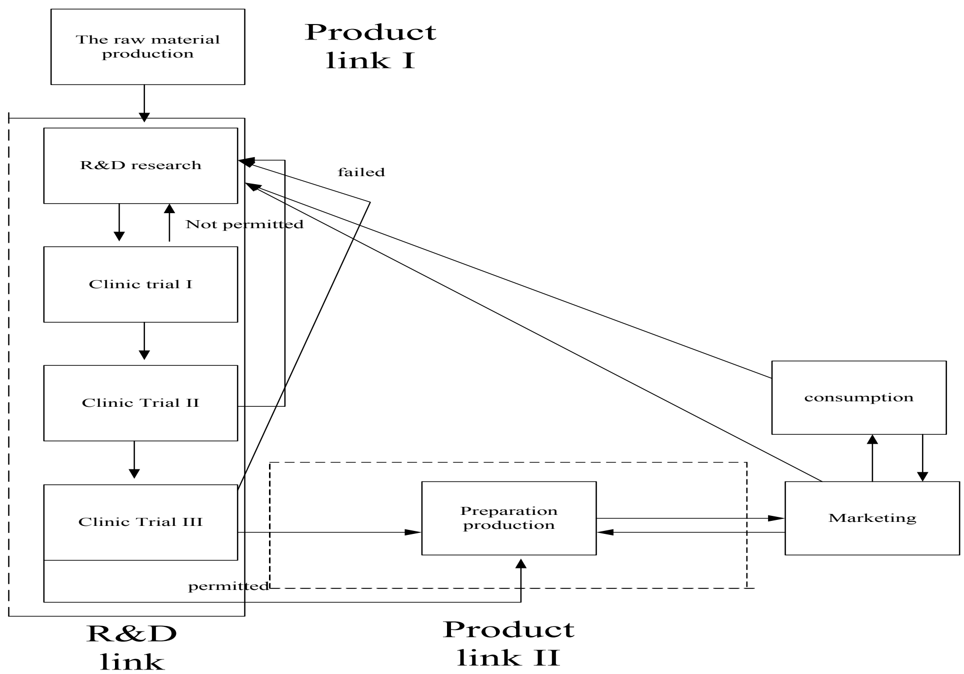


Table 2: Comparison of the R&D intensity of China and Selected Developed Countries

	China	USA	Japan	Germany	France	England	Korea
	2007	2006	2006	2006	2006	2006	2006
Manufacture	3.5	10.2	11	7.6	9.9	7	9.3
High-tech industry	6	39.8	28.9	21.5	31.9	26.6	21.3
Pharmaceutical industry	4.7	46.2	37.1	23.9	33.4	42.3	6.3

Source: Ministry of Science and Technology of the People's Republic of China

The R&D intensity of Chinese medicine manufacturers is just a bit higher than the average level of the manufacturing industry, which is far lower than developed countries, and also lower than the average level of the Chinese high-tech industry. Thus, the R&D stage is not China's comparative advantage within the medicine manufacturing industry. Using Gereffi's classification of value chains (table 1), we can conclude that the Chinese pharmaceutical industry's value chain is buyer-driven.

IV. Empirical research on international specialization in the global pharmaceutical industry

Given this analysis of the global pharmaceutical industry value chain, we make some hypotheses about international specialization in the industry:

Hypothesis 1: Intra-industry trade (IIT) is the dominant form of trade in global medicine among developed countries

We expect that medicine, especially the final product stage of the value chain, is typically technology- intensive, and has no labor intensive stages. Developed countries have a significant advantage in high-tech fields, compared to developing countries. Thus, we expect that the pharamceutical trade among developed countries is largely IIT.

Table 3 shows the breakdown of global pharmaceutical trade by country. Shares are calculated from United Nations Commodity Trade Statistics.[2]

Table 3: The distribution of global pharmaceutical trade

	Share of Global Exports	Share of Global Imports
	2008	2008
Developed Countries:	90.55%	80.15%
EU15 and Switzerland	80.02%	56.85%
USA	7.98%	15.73%
Canada	1.53%	2.84%
Australia	0.86%	1.84%
Japan	0.89%	2.90%
Other Countries:	9.45%	19.85%
India	1.51%	0.53%
China	1.81%	1.45%

Source: Calculated from U.N. commodity trade statistics.

[2] There is still no agreement on the statistical classification for various medicines in foreign trade. Given this limitation, this article uses the following rules of classification. Products in HS 2935-2941 cover 95 percent of chemical raw medicines; products in HS 3003-3004 cover almost all chemical preparations, plant preparations, Chinese medicine preparations and part of the biological preparations. This study does not include general medical supplies like bandages, medical splints, and medical boxes in the preparations product category.

The results show that most of the world pharmaceutical trade is conducted among developed countries; about 91 percent of medicine exports and 80 percent of medicine imports supply are in 20 developed countries. Developing countries, such as China and India, are beginning to develop an international specialization in this industry, but they still account for a very small portion of global pharmaceutical trade.

To assess how specialized developed countries are in the pharmaceutical industry, we use the 1975 Grubel & Lloyd (GL) index of IIT. The GL index is defined as follows:

$$GL_j = \frac{\sum_{i=1}^{N}(X_i + M_i) - \sum_{i=1}^{N}(|X_i - M_i|)}{\sum_{i=1}^{N}(X_i + M_i)} \times 100$$

X_i, export of the i product; M_i, import of the i product

The GL indices of manufactured medicine products and medicine raw materials of United States, United Kingdom, Switzerland, France, and Germany in 2004 and 2008 are provided in table 4. Every country's GL index is over 0.5 and some countries' GL index such as France and Germany shows a clear rising trend. This proves that the intra-industry division in developed countries is the main type of international specialization of the global pharmaceutical industry. From the perspective of product structure, we can see that the GL index of raw medicine as intermediate product is comparatively low, while the GL index of main trade product-pharmaceutical preparation is comparatively high.

Hypothesis 2: Most of global pharmaceutical trade is in final products. Intermediate products account for a small share of trade.

International trade theory shows that trade in intermediate product greatly relies on two points: the spatial separability of production, and differing factor intensities across the stages in the global chain. We expect that the degree of separability in production links in proprietary medicine is low; thus, final product trade will be the dominant type of global pharmaceutical IIT.

Table 4: The GL Index of Pharmaceutical products in Five Developed Countries

	Year	GL index of total pharmaceutical trade	GL index of raw medicine	GL index of manufactured products trade
France	2004	73.25	48.98	76.78
	2008	78.54	60.77	80.19
Germany	2004	59.2	57.8	59.33
	2008	61.34	40.41	63.08
Switzerland	2004	66.87	46.66	70.03
	2008	57.26	51.7	57.82
England	2004	77.97	57.48	79.36
	2008	75.8	80.06	75.6
USA	2004	69.58	77.66	67.96
	2008	63	65.91	62.51

Source: Calculated from U.N. commodity trade statistics.

We treat raw medicine as an intermediate product in the global pharmaceutical industry, and all kinds of prepared medicines as final products. In table 5 we show the ratio of final products and intermediate products in global pharmaceutical trade in 2008. The result demonstrates that hypothesis 2 is correct, and trade is mainly composed of trade in final products.

Table 5: The proportion of intermediate product trade and final product trade

	Prepared Medicine trade (2008)	Raw medicine trade (2008)
	(Final product)	(Intermediate product)
Proportion of export	90.40%	9.60%
Proportion of import	90.59%	9.41%

Source: Calculated from U.N. commodity trade statistics.

Hypothesis 3: Most of the trade between the developed countries is horizontal intra-industry trade.

Intra-industry trade can be divided in two parts: horizontal intra-industry trade (HIIT) and vertical intra-industry trade (VIIT). HIIT means the technological level of import and export is similar, while VIIT means the technological level is different. Fukao & Ishido (2004) proposes the following criteria to judge whether trade is HIIT or VIIT.

$$\frac{Min(M_{kk'j}, M_{k'kj})}{Max(M_{kk'j}, M_{k'kj})} \leq 0.1 \text{ unilateral trade;}$$

$$0.1 \leq \frac{Min(M_{kk'j}, M_{k'kj})}{Max(M_{kk'j}, M_{k'kj})} \leq 10 \;\; 0.8 \leq \frac{P_{kk'j}}{P_{k'kj}} \leq 1.25 \text{ horizontal inter-industry trade}$$

$$0.1 \leq \frac{Min(M_{kk'j}, M_{k'kj})}{Max(M_{kk'j}, M_{k'kj})} \leq 10 \;\; 0.8 \leq \frac{P_{kk'j}}{P_{k'kj}} \geq 1.25 \; \frac{P_{kk'j}}{P_{k'kj}} \leq 0.8 \text{ vertical inter-industry trade}$$

$M_{kk'j}$:country k export to country k' in commodity j $P_{kk'j}$: the price, 0.1 1.25 and 0.8 threshold

Based on the method given by Fukao and Ishido, we calculate separately the proportion of unilateral trade, HIIT and VIIT, in the trade between France, Germany, and the United States, shown in table 6. The results support hypothesis 3.

Table 6: The proportion of unilateral trade, VIIT and HIIT

	Proportion of unilateral trade (2008)	Proportion of vertical intra-industry trade (2008)	Proportion of horizontal intra-industry trade (2008)
Germany and USA	20.89%	30.11%	49.01%
France and USA	16.28%	10.97%	72.75%

Source: Calculated from U.N. commodity trade statistics.

V. Empirical Study on the Chinese Pharmaceutical Industry Division

The pharmaceutical industry value chain production link is relatively simple, and is divided into raw medicine production and prepared medicine production. We can judge the position of the Chinese pharmaceutical industry in international specialization according to Trade Competitive Index (TC Index) (of Chinese raw medicine and prepared medicine).

We calculate the Trade Competitive Index (2004-2008) for China and India's raw and prepared medicine, as shown in tables 7 and 8. We can see from the chart that China and India both have a certain degree of overall competitiveness in the pharmaceutical industry, but the origin of the competitiveness differs greatly. The Chinese TC index is very high for raw medicine, showing that

China has absolute comparative advantage in raw medicine production; while India is located at a relatively low position. In prepared medicine, China is located at a low position and the TC index has a falling trend; while India has a remarkable advantage. Thus we can infer that since 2004, in the global pharmaceutical value chain production link, China is mainly specialized in raw medicine, while India is specialized in prepared medicine.

Table 7: The TC index of China's and India's pharmaceutical trade

Year	TC index of China	TC index of India
2004	0.19	0.55
2005	0.17	0.5
2006	0.17	0.49
2007	0.15	0.47
2008	0.13	0.52

Source: Calculated with data from U.N. commodity trade statistics and China's customs.

Table 8: The TC index of China and India intermediate product trade and preparation product trade

Year	Intermediate products		Preparation products	
	TC index of China	TC index of India	TC index of China	TC index of India
2004	0.73	-0.01	-0.56	0.76
2005	0.74	-0.11	-0.56	0.74
2006	0.78	-0.15	-0.58	0.7
2007	0.79	-0.13	-0.58	0.7
2008	0.8	-0.06	-0.6	0.71

Source: Calculated with data from U.N. commodity trade statistics and China Customs.

We can draw the same conclusion using the intra-industry trade analysis method. Because we calculate the TC index of both raw medicine and preparation, so we also can use intra-industry trade method to analyze the China's pharmaceutical trade. Tables 9 and 10 show the GL indices of China and India from 2004 to 2008, as well as both countries' bilateral trade, vertical inner trade, and horizontal trade ratio in pharmaceutical trade.

Table 9: The GL index of China's and India's pharmaceutical trade

Year	GL index of China	GL index of India
2004	34.45	38.26
2005	33.76	39.1
2006	31.16	40.04
2007	30.62	42.4
2008	29.32	40.11

Source: Calculated with data from U.N. commodity trade statistics and China Customs.

Table 10: The proportion of unilateral trade, VIIT and HIIT in China and India

		Unilateral trade (import)	Unilateral trade(export)	VIIT	HIIT
China	**Total medicine trade**	34.03%	53.12%	12.85%	0.00%
	Prepared medicine trade	87.95%	0.00%	12.05%	0.00%
	Raw medicine trade	0.00%	85.92%	14.08%	0.00%
India	**Total medicine trade**	8.96%	0.00%	89.86%	1.18%
	Prepared medicine trade	0.00%	0.00%	95.19%	4.81%
	Raw medicine trade	0.00%	12.74%	87.26%	0.00%

Source: Calculated with data from U.N. commodity trade statistics and China's customs.

The degree of IIT in Indian pharmaceutical products is obviously higher than that of China, and closer to developed countries in Europe or the United States. Using the method of Fukao & Ishido (2003), we can also see that China's raw medicine tends to be unilaterally exported, while the leading industry – manufactured medicine products – tends to be unilaterally imported. So these trade flows are not characterized by intra-industry trade. India's IIT is basically vertical in both raw medicine and prepared medicine, and the degree of participation in IIT is much higher than China's.

China's status in raw medicine in the global pharmaceutical value chain is not a good sign for the development of the Chinese pharmaceutical industry.

As described above, in the nonproprietary medicine field, raw medicine production has a weak connection with the core link of the value chain – the R&D link – while prepared medicine production has a closer connection. Thus, raw medicine production is the lowest end link in the nonproprietary medicine value chain, while R&D and production of prepared medicines are at the relatively high end. So we can conclude that China's international specialization within the nonproprietary medicine chain is at the lowest end of the "smile curve," while India is located at the relatively high end.

Because raw medicine production is one of the links in final production of prepared medicines, the Chinese pharmaceutical industry has the characteristics of vertical specialization. Vertical specialization refers to the international fragmentation of different production links in the same product in same industry, across countries. It is a new type of vertical industry division, and is also the main type of intra-industry division between developed countries and developing country. Raw medicine production in China embodies higher efficiency because of multinational companies' vertical specialization.

But there is a great difference between vertical specialization in the medicine industry and in the IT industry. On the one hand, though there is weak connection between raw medicine production and core R&D link, raw medicine production is still a capital intensive industry link and has higher technical and capital requirements than the assembly link of the IT industry. Therefore, though China is now located at the lowest end in the world medicine value chain, the added value in this link is much higher than in the assembly link of IT industry. On the other hand, the assembly link of the IT industry is located at the end of its value chain, and the products are directly for sale. In contrast, raw medicine is located at the front part of the medicine production chain. Outsourcing this link could reduce cost to some degree, but might produce more uncertainty for the subsequent high value-added links, thus enlarging production risk. Thus, the degree of vertical specialization in the Chinese medicine industry may be far lower than in the IT industry. Lastly, the relation between vertical specialization and processing trade is weaker than in manufacture industries such as IT.

We used the Input-Holding-Output Model of the Non-Competitive Imports Type Capturing China's Processing Exports by Chen Xikang and Zhu Kunfu (2008) to calculate the VS index and domestic value-added ratio. With their help, we constructed the Input-Holding-Output Model, which includes 43 sectors in 2002. We used the 42 sector Input-Holding-Output Model, the

123 sector Input-Holding-Output Model, and processing trade in Chinese medicine. All data are from 2002. The resulting VS share and domestic value-added share are shown in tables 11 and 12.

The results support our initial assumption. The Total VS index value for the pharmaceutical industry is 0.38, and for processing trade is 0.59—slightly higher than some light industries like food and textiles, but far lower than the IT or transport equipment industries. Therefore, the domestic value added of Chinese pharmaceutical production is very high (0.618). This implies that each $1,000 worth of pharmaceutical exports, yields China $618 worth of domestic value-added earnings—1.63 times that which is brought through communication equipment, computers, and other electronics equipment exports. All this demonstrates that the local added value of the domestic pharmaceutical industry is much higher than that of the IT industry, though they are both situated at the lowest end of the value chain.

Other data also support this conclusion. The main indirect evidence comes from processing trade in the Chinese pharmaceutical industry. The main way of participating in vertical specialization is by processing trade. But processing trade is comparatively low in foreign content. We compare the share of processing exports with general exports between China and the United States, using data provided by United States International Trade Commission. The results are in table 13.

Table 11: The VS index in the pharmaceutical industry in 2002

	Direct VS index			Total VS Index		
	General Trade	Processing Trade	Total	General Trade	Processing Trade	Total
Manufacture of food products and tobacco processing	0.0013	0.5075	0.1115	0.0081	0.5664	0.19
Textile goods	0.0025	0.6389	0.1991	0.0124	0.6977	0.273
Wearing apparel, leather, furs, down and related products	0.0022	0.5929	0.198	0.0113	0.6616	0.2829
Sawmills and furniture	0.0025	0.5831	0.1798	0.013	0.6514	0.3175
Paper and products, printing and record medium reproduction	0.003	0.5399	0.2059	0.0127	0.6147	0.341
Petroleum processing, coking and nuclear fuel processing	0.0546	0.7302	0.684	0.0705	0.7755	0.7326
Chemicals	0.0071	0.6416	0.3592	0.0237	0.7267	0.5303
Medicine industry	**0.0042**	**0.5253**	**0.2732**	**0.0129**	**0.5937**	**0.3816**
Nonmetal mineral products	0.0045	0.5512	0.2482	0.0175	0.628	0.3962
Metals smelting and pressing	0.0061	0.6917	0.281	0.0224	0.737	0.4715
Metal products	0.0034	0.7382	0.2323	0.0189	0.776	0.4589
Common and special equipment	0.0072	0.6944	0.3709	0.0213	0.7466	0.5284
Transport equipment	0.0066	0.6905	0.3257	0.0214	0.7552	0.5369
Electric equipment and machinery	0.0079	0.7239	0.3443	0.0227	0.7723	0.5189
Telecommunication equipment, computer and other electronic equipment	**0.0058**	**0.8221**	**0.5112**	**0.0201**	**0.8419**	**0.621**
Instruments, meters, cultural and office machinery	0.0489	0.6062	0.3626	0.0629	0.6408	0.5103

Table 12: The domestic value-added ratio in the pharmaceutical industry in 2002

	DVA			TVA		
	General Trade	**Processing Trade**	**Total**	**General Trade**	**Processing Trade**	**Total**
Manufacture of food products and tobacco processing	0.3403	0.1701	0.2132	0.9919	0.4336	0.81
Textile goods	0.2896	0.1357	0.1761	0.9876	0.3023	0.727
Wearing apparel, leather, furs, down and related products	0.3233	0.1346	0.1857	0.9887	0.3384	0.7171
Sawmills and furniture	0.3148	0.1494	0.1923	0.987	0.3486	0.6825
Paper and products, printing and record medium reproduction	0.3772	0.1843	0.2409	0.9873	0.3853	0.659
Petroleum processing, coking and nuclear fuel processing	0.1835	0.0942	0.1177	0.9295	0.2245	0.2674
Chemicals	**0.2754**	**0.1355**	**0.1735**	**0.9763**	**0.2733**	**0.4697**
Medicine industry	**0.4148**	**0.2397**	**0.2827**	**0.9871**	**0.4063**	**0.6184**
Nonmetal mineral products	0.355	0.1801	0.2254	0.9825	0.372	0.6038
Metals smelting and pressing	0.2596	0.1336	0.1671	0.9776	0.263	0.5285
Metal products	0.2665	0.1296	0.1678	0.9811	0.224	0.5411
Common and special equipment	0.314	0.1538	0.1948	0.9787	0.2534	0.4716
Electric equipment and machinery	0.2817	0.1322	0.1818	0.9773	0.2277	0.4811
Telecommunication equipment, computer and other electronic equipment	**0.2655**	**0.1151**	**0.1749**	**0.9799**	**0.1581**	**0.379**
Instruments, meters, cultural and office machinery	0.1883	0.2888	0.0891	0.9371	0.3592	0.4897

Table 13: The proportion of general trade and processing trade between China and the United States in the pharmaceutical industry

		2006	2007	2008
Total	Proportion of General trade	81.95%	87.42%	81.09%
	Proportion of Processing trade	11.25%	11.64%	16.60%
Raw medicine	Proportion of General trade	81.45%	87.11%	80.93%
	Proportion of Processing trade	18.02%	12.08%	16.81%
Prepared medicine	Proportion of General trade	98.53%	95.07%	82.77%
	Proportion of Processing trade	0.53%	0.52%	14.32%

Source: Calculated with data from China customs.

We can see that the share of exports in the medicine industry classified as processing is floating around 15 percent—far lower than the average share of processing across all Chinese exports, which exceeds 40 percent.

Additional evidence comes from the company structure of Chinese pharmaceutical exports. Multinational companies (MNCs) account for a smaller share of Chinese medicine exports than IT exports. It is estimated that only 33.1 percent of the medicine exported to the United States are done by foreign-invested companies. The other two-thirds are done by local companies. Even in processing trade, Chinese local companies have an advantageous position. In 2008, Chinese local companies' share of processing exports to the United States in medicine was about 68 percent. The proportion of foreign-invested companies is over 80 percent in overall processing exports.

These results show that the Chinese pharmaceutical industry, though participating in global vertical specialization to some degree, is not led by foreign-invested companies. Instead, it is the result of local companies seeking to maximize the benefits of, and actively participating in, international specialization.

This paper mainly analyzes China's position in the global pharmaceutical industry value chain. Within the R&D link, multinational companies intend to move clinical trials to China. As described above, the R&D trial link is different from the previous two links, which require not only high-tech talent but also large amounts of labor to generate sufficient experimental data. Therefore, China has a relative advantage in clinical trials. The cost of clinical trials is much higher in developed countries than in China, due to the high resident income of developed countries. Also, the clinical trial's function is mainly to offer database support. Thus technical spillover effects are far lower than in other links and multinational companies' monopoly in technology is far less important.

In order to support this conclusion, we provide some statistics on multinational companies' clinical trials and pharmaceutical companies' data based on the largest registered clinical trial database, "clinicaltrials.gov," and data from China's High-Tech Statistical Yearbook. The results in table 14 show that in 2007, multinational companies' clinical trials in China increased 74 percent over those in 2005, while the ratio of value added grew only 57 percent over the same period.

Table 14: Clinical trials in China

Year	Clinical trial number by MNC	MNC number	Value-added by MNC (100 MRMB)
2005	79	707	364.05
2006	123	739	432.9
2007	137	797	570.12

Due to the increasing demand for clinical trial candidates throughout Phases I to IV (from tens of candidates in Phase I to thousands in Phase IV), Phases III & IV have more expenditures for collecting sample data. Thus, we can prove the cost advantage in Chinese clinic trial by analyzing the structure of multinational companies' clinical trials in China. The results are shown in table 15. In MNC clinical trials in China, the labor cost proportions are higher in Phases III & IV than in MNC trials worldwide. We can conclude that the main reason for conducting clinical trials in China is because of the lower labor cost.

Table 15: Clinical trials I-IV in China and Worldwide by MNCs

	MNC trials in China				MNC trials Worldwide			
Year	Phase I	Phase II	Phase III	Phase IV	Phase I	Phase II	Phase III	Phase IV
2005	2.56%	16.67%	55.13%	25.64%	8.66%	32.14%	38.78%	20.41%
2006	5.79%	9.92%	69.42%	14.88%	15.04%	32.52%	34.68%	17.76%
2007	5.69%	17.89%	55.28%	21.14%	20.46%	35.33%	27.59%	16.61%
2008	8.21%	9.70%	53.73%	28.36%	25.07%	32.77%	25.94%	16.22%

Part 6 Conclusion

This paper is an empirical study of China's position, or international specialization, in the global pharmaceutical value chain. From our analysis, we draw the following conclusions. First, compared to other manufacturing industries, the pharmaceutical industry value chain has a complicated R&D link and a lower degree of modularization in its production link. These characteristics imply that the main type of division in the pharmaceutical industry is horizontal intra-industry trade among developed countries.

Second, proprietary medicine and nonproprietary medicine have clear differences in their value chain. The degree of modularization of the non-patent prepared chemicals value chain is higher than proprietary medicine, and nonproprietary medicine has less demand for R&D in the raw medicine production link. This gives the pharmaceutical industry some degree of vertical specialization.

Third, the unique clinical trials in R&D links in the pharmaceutical industry have the characteristics of strong modularity, low technical spillovers, and high labor intensity. These make outsourcing the main type of vertical specialization in the R&D links. Experimental results show that lower cost motivates multinational companies to transfer clinic trials to China.

Fourth, the characteristics of low R&D expenditures and small scale enterprises imply that China mainly participates in vertical specialization in nonproprietary raw medicine production. But the degree of vertical specialization is far less than in the IT industry. This link is the lowest end of the global value chain in pharmaceutical products.

Finally, the VS index shows a low level of foreign content and that processing trade is dominated by local companies. Though the pharmaceutical and IT industries are both in the lowest end of their value chains, the domestic value-added ratio for the pharmaceutical industry is higher than that of the IT industry.

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