Analysis on Competitive Advantages of Research and Development Factor in International Trade

—Take the global semiconductor industry as an example

Hu Jiajun

Shanghai University, Shanghai Tobacco Storage & Transportation Co.,Ltd
E-mail:181670931@qq.com

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Abstract: The Research and Development Factor (R&D Factor) was first proposed in a paper jointly published in February 1967 by W. Gruber, D. Meita, and R. Vernon. They studied the interrelationship between U.S. industrial development investment and foreign trade commodity structure, and explained Lyon's “mystery” from a technical point of view. This paper compares and analyzes the ranking and competitiveness of China's semiconductor companies in the world's top ten semiconductor companies by taking advantage of the trade competitiveness index. The results show that the research and development elements of the US semiconductor industry have an absolute advantage and their status is difficult to shake, but the trade deficit appears. Although China's chip industry holds a certain share in international trade, the trade deficit is excessive, and high-end products mainly rely on imports, and the competitive advantage is not obvious. It is necessary to pay more attention to the importance of research and development factors and adopt effective policy measures to accelerate the enhancement of China’s semiconductor industry’s international competitiveness.

1. Introduction

The chip generally refers to the carrier of the integrated circuit and is an intuitive product of the semiconductor industry. In 2017, the global semiconductor industry sales category includes integrated circuits (83.253%, China Industry Information), optoelectronic devices (8.445%), discrete devices (5.252%), and sensors (3.050%). From the perspective of industry segments, the integrated circuit industry mainly includes memory chips (36.12%), logic chips (29.78%), processor chips (18.63%), and analog chips (15.46%). The integrated circuit industry is divided into equipment materials, chip design, chip manufacturing, and chip packaging and testing. Due to the rapid development of China's downstream applications such as Internet of things, 5G, smart terminals, artificial intelligence, virtual reality, block chain and other emerging industries, the midstream IC industry has grown rapidly.

In 2017, China imported 370 billion pieces of ICs, with an import amount of USD 260.14 billion [customs data, CSIA], exceeding the crude oil import value of USD 191.83 billion [Ministry of

Commerce]. It is China’s largest import commodity, and the contradiction between supply and demand is particularly prominent. China's domestic integrated circuit industry reached a size of 81.6 billion US dollars [SEMI], and its chip self-sufficiency rate was only 23.88%. High-end chips such as general-purpose CPUs and memory are almost all dependent on imports. Why does China's chip industry need to rely heavily on imports? What is the competitiveness of China's chip industry in international trade? Understanding these issues is a necessary prerequisite for us to correctly assess the level of development of China's chip industry and correctly formulate the participation in international trade competition.

2. Analysis of Semiconductor Industry Competitiveness

According to the data released by the Semiconductor Industry Association of America (SIA), the total global semiconductor industry sales in 2017 were 412.2 billion U.S. dollars, a year-on-year increase of 21.6%, which are the highest sales ever in the industry. "A strong semiconductor industry is the foundation of the U.S. economic strength, national security, and global technology leadership", Neuf said. "We urge the Congress and the Trump administration to formulate policies in 2018 to promote innovation in the United States and allow American companies to compete with their foreign counterparts in a more equitable competitive environment". It can be seen that semiconductor materials are constantly being implanted into all aspects of life. The scale of the economy and the level of technology and technology are all sufficient to affect national security. Therefore, it is essential for the development of the semiconductor industry to lay emphasis on the development of the semiconductor industry.

2.1 Analysis of Trade Competitive Advantage Index

The Trade Competitive Advantage Index, or TC Index, also known as the Comparative Advantage Index, is a powerful tool for the analysis of the international competitiveness of the industry structure. It can generally reflect the comparative advantages of the computing objects. Because it eliminates inflation and the size of the country, it makes international data incommensurable. Therefore, the comparative advantage index is quite comparable. The formula is: CAI=(Xij-Mij)/(Xij+Mij), value range [-1,1], close to 0, indicating that the comparative advantage is close to the average level, the import and export crossover is obvious; when the comparative advantage index value A value greater than 0 and closer to 1 indicates that the comparative advantage is greater; otherwise, it indicates that the comparative advantage is smaller.

Table 1. Competition Index of Major Semiconductor Trade Countries in the World from 2013 to 2017

年份 / 国家	2013	2014	2015	2016	2017
美国	0.014	-0.006	-0.038	-0.078	-0.060
韩国	0.245	0.264	0.243	0.259	0.408
日本	0.205	0.168	0.132	0.140	0.129
中国	-0.450	-0.563	-0.537	-0.574	-0.591
中国台湾	0.295	0.318	0.337	0.333	0.328

Data source: Calculated from CSIA, WIND, Ministry of Commerce data

The CAI index was calculated using the import and export data of the semiconductor industry in five countries and regions. The results are shown in Table 1.

As can be seen from Table 1, South Korea, Japan, and China Taiwan are positive in 2013-2017, indicating that these three countries and regions have been net exporters of semiconductor trade for the past five years and have strong trade competitiveness. China is all around -0.5, indicating that the export competitiveness of semiconductor trade is the weakest. It is worth noting that the use of the TC method to show that the US semiconductor industry deficit in the past four years shows that whether the US semiconductor industry is on the decline? This is contrary to the usual people's impression of the US semiconductor industry. The answer is no, and the reasons are shown below.

3. The Status Quo of Research and Development of Semiconductor Industry in the World

Michel E. Porter, a professor at Harvard University, believes that a country's competitive advantage is a competitive advantage between the company and the industry. The fundamental reason for the rise and fall of a country is whether it can gain a competitive advantage in the international market. The 21st century is an era of information technology. The use of modern information technology directly affects the comparative advantages of a country, thereby affecting a country's international division of labor and international trade status. Under the background of economic globalization (T. Levy in 1985), due to the different strengths of information technology, developed countries and transnational corporations that master the most advanced technologies have curbed the transformation and development of developing countries and the transformation of international trade status.

3.1 Structure of World Semiconductor Industry

Table 2 Revenue rankings of the top ten global Fabless companies in 2017

2017E 排名	企业名称	总部	2016 Tot IC	2017E Tot IC	2017/2016 %Change
1	高通	美国	15,414	17,078	11%
2	博通	新加坡	13,846	16,065	16%
3	英伟达	美国	6,389	9,228	44%
4	联发科	中国台湾	8,809	7,875	-11%
5	苹果	美国	6,493	6,660	3%
6	AMD	美国	4,272	5,249	23%
7	海思半导体	中国	3,910	4,715	21%
8	赛灵思	美国	2,311	2,475	7%
9	美满电子	美国	2,407	2,390	-1%
10	紫光展锐	中国	1,880	2,050	9%
前十总和			65,731	73,785	12%
其它			24,694	26,825	9%
总和			90,425	100,610	11%

Data source: Ic Insights

In the ranking of the top ten Fabless companies in the world in 2017, American companies accounted for six (excluding Broadcom), and global market share reached 42.8%. China Hess Semiconductor and Ziguang Zengru were on the list with a market share of 6.7%. It can be seen that the US semiconductor industry has absolute advantages in the global Fabless subdivision industry and is a capital-intensive and technology-intensive industry.

Table 3 Revenue rankings of top ten global foundry companies in 2017

2017E 排名	企业名称	总部	2016	2017E	2017/2016 %Change	2017E 市占率
1	台积电	中国台湾	29,347	31,942	8.8%	55.9%
2	格罗方德	美国	4,983	5,391	8.2%	9.4%
3	联华电子	中国台湾	4,574	4,883	6.8%	8.5%
4	三星	韩国	4,271	4,385	2.7%	7.7%
5	中芯国际	中国	2,905	3,089	6.3%	5.4%
6	高塔半导体	以色列	1,245	1,382	11.1%	2.4%
7	力晶	中国台湾	868	1,032	19.0%	1.8%
8	世界先进	中国台湾	799	814	2.0%	1.4%
9	华虹宏力	中国	719	805	11.9%	1.4%
10	东部高科	韩国	664	673	1.5%	1.2%

Date source: Zero2IPO Research Center

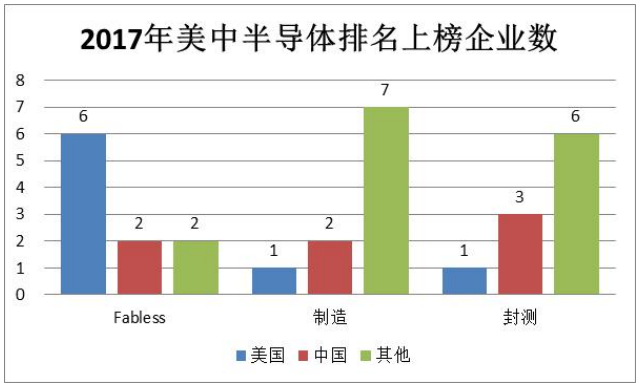
In the ranking of the top ten global wafer foundry companies in 2017, there was only one in the United States with a market share of 9.4%. There are two companies in China with a market share of 6.8%. There are four in Taiwan, China, and accounting for 67.6% of the market in the international division of chip foundry.

Table 4 Top Ten Global Packaging and Metering Plants in 2017

2017E 排名	企业名称	总部	2016	2017E	2017/2016 %Change	2017E 市占率
1	日月光	中国台湾	75,092	79,862	6.4%	19.2%
2	安靠	美国	59,724	62,316	4.3%	15.0%
3	长电科技	中国	44,080	49,586	12.5%	11.9%
4	矽品	中国台湾	40,276	41,166	2.2%	9.9%
5	力成	中国台湾	22,991	29,034	26.3%	7.0%
6	天水华天	中国	12,623	16,196	28.3%	3.9%
7	通富微电	中国	10,567	13,957	32.0%	3.3%
8	京元电	中国台湾	9,555	10,353	8.3%	2.5%
9	联测	新加坡	10,567	10,337	-2.2%	2.5%
10	南茂	中国台湾	8,712	9,141	4.9%	2.2%

Date source: Zero2IPO Research Center

In 2017, only one of the world's top ten packaging and testing plants was in the United States, with a market share of 15%. China has 3 companies in the relatively low technological barriers and testing industry, with a market share of 24.8%. There are five companies in Taiwan, with a market share of 52.7%.



Date source: According to the above data

Figure 1 Number of companies listed in the US and China Semiconductors in 2017

From the chip design, manufacturing, packaging and testing companies to comprehensive analysis of the rankings, the US semiconductor industry's competitive advantage in the chip design industry. Taiwan's revenue has been for OEMs such as Intel, which has completed the initial accumulation and technological advantages of the semiconductor industry and has a competitive advantage in the manufacturing and packaging and testing industries. However, due to the late start of the Chinese mainland enterprises, they face the blocking of the technology market by foreign semiconductor companies. Although the IC design and packaging and testing industry has made great progress in recent years, it is subject to technological backwardness and the related industries still meet the characteristics of labor-intensive industries.

3.2 Semiconductor Industry R&D Investment

Table 5 Top Ten Semiconductor Manufacturers' R&D Expenditure in 2017

2017年排名	总部	公司	成立时间	研发支出 ($M)	研发/销售 (%)	与16年同比 Chg in R&D
1	美国	英特尔	1968	13098	21.2%	3%
2	美国	高通	1985	3450	20.2%	-4%
3	新加坡	博通	1991	3423	19.2%	4%
4	韩国	三星	1938	3415	5.2%	19%
5	日本	东芝	1875	2670	20.0%	-7%
6	中国台湾	台积电	1987	2656	8.3%	20%
7	中国台湾	联发科	1997	1881	24.0%	9%
8	美国	美光	1978	1802	7.5%	8%
9	美国	英伟达	1993	1797	19.1%	23%
10	韩国	海力士	1983	1729	6.5%	14%
			合计	35921	13.0%	6%

Date source: Ic Insights

In 2017, the world's top ten semiconductor manufacturers' R&D expenditures show that the U.S. companies (excluding Broadcom) spent US$20.147 billion, accounting for 56.1% of the total. South Korea's two companies spent a total of US$5.14 billion, accounting for 14.32%. Two companies in Taiwan, China, invested US$4.537 billion, accounting for 12.6% of the total, Japan's one company accounted for 7.4%, and Singapore's one company accounted for 9.5% (Broadcom). China has no company on the list.

According to data from Ic Insights, last year's top 10 semiconductor manufacturers spent 35.921 billion US dollars in research and development, an increase of 6%, exceeding the total sum of research and development of other semiconductor companies by 23 billion US dollars. Among them, Intel is the leading company in the integrated device manufacturer (IDM), which has an R&D expenditure of 13.09 billion U.S. dollars in 2017, accounting for 36% of the total expenditure of the group, accounting for 21.2% of the total sales, which is higher than 2010. 16.4% of the year and 9.3% in 1995. Intel's R&D exceeds the total of the four companies ranked behind: Qualcomm, Broadcom, Samsung and Toshiba.

It is worth noting that Huawei, as the actual holding company of Hass Semiconductor, stated in its 2017 annual report that it invested US$13.75 billion for R&D expenses, accounting for 14.9% of the sales ratio. Over the years, Huawei has promised that annual R&D investment will not be less than 10% of sales, and in fact it is higher than 14% for many years. Ziguang Zengrui's parent company Ziguang Group's 2017 annual report showed that a total of 770 million U.S. dollars was

invested in R&D, which accounted for 27.49% of sales, and the number of R&D personnel increased by 8.17% compared to 2016. The ZTE annual report shows that the annual research and development expenses are more than 10%. It can thus be seen that the leading companies in China's chip industry recognize that R&D factors are in line with world-class manufacturers as a necessary condition for maintaining their competitiveness.

The case of China-US trade frictions ignited by the ZTE Corporation Act 301 as the fuse of the United States has fully demonstrated the importance of research and development factors for a company and even a country. The emphasis and input on research and development elements are the only way for developing countries to transform and develop and to get rid of the labor-intensive international division of labor status.

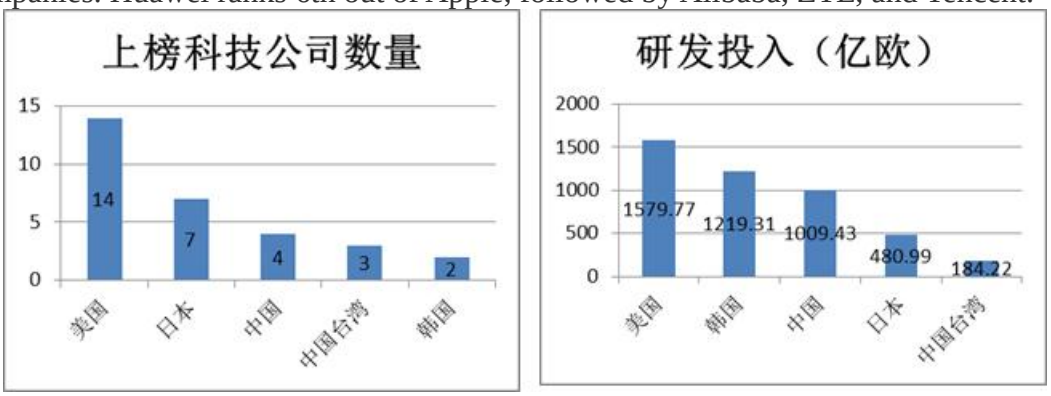
3.3 Ranking of EU Releases 2017 Industrial R&D Investment

Table 6 Global R&D investment of Internet, electronic information, and semiconductor companies in 2017 (100 million euros)

序号	排名	公司	国家	研发支出	销售额	研发/销售
1	2	ALPHABET	美国	128.64	856.39	15.0%
2	3	微软	美国	123.68	853.34	14.5%
3	4	三星电子	韩国	121.55	1585.71	7.7%
4	5	英特尔	美国	120.86	563.39	21.5%
5	6	华为	中国	103.63	539.2	19.2%
6	7	苹果	美国	95.3	2045.72	4.7%
7	17	甲骨文	美国	58.43	357.92	16.3%
8	18	思科	美国	57.48	455.41	12.6%
9	19	FACEBOOK	美国	56.15	262.2	21.4%
10	25	西门子	德国	56.15	262.2	21.4%
11	26	IBM	美国	49.39	758.17	6.5%
12	27	诺基亚	芬兰	49.04	236.14	20.8%
13	28	高通	美国	48.87	223.45	21.9%
14	40	松下	日本	38.52	596.47	6.5%
15	41	索尼	日本	36.34	617.55	5.9%
16	44	爱立信	瑞典	32.95	233.04	14.1%
17	47	四爱普	德国	30.37	220.62	13.8%
18	51	戴尔	美国	26.92	584.78	4.6%
19	54	日立	日本	26.31	744.18	3.5%
20	55	博通	新加坡	25.37	125.61	20.2%
21	56	佳能	日本	24.56	276.28	8.9%
22	57	东芝	日本	24	395.62	6.1%
23	58	阿里巴巴	中国	23.29	216.05	10.8%
24	59	西部数据	美国	23.16	181.13	12.8%
25	63	台积电	中国台湾	20.92	278.45	7.5%
26	70	中兴	中国	18.61	138.19	13.5%
27	78	意大利电信	意大利	17.48	190.25	9.2%
28	81	NTT	日本	17.19	925.21	1.9%
29	83	SK 海力士	韩国	16.47	135.09	12.2%
30	84	联发科	中国台湾	16.36	80.92	20.2%
31	85	腾讯	中国	16.17	207.4	7.8%
32	87	AT&T	美国	15.64	1553.78	1.0%
33	89	美光	美国	15.34	177.63	13.0%
34	93	三菱电机	日本	15.02	344.27	4.4%
35	94	鸿海精密	中国台湾	15.02	1280.33	1.2%
36	96	应用材料	美国	14.59	102.69	14.2%
37	98	恩智浦	荷兰	14.41	90.11	16.0%

Data Source: According to the EU released and organize

In 2017, the world's industrial R&D investment rankings were released. There are 37 Internet companies, electronic information companies, and semiconductor companies. Among them, China has 4 companies. Huawei ranks 6th out of Apple, followed by Alibaba, ZTE, and Tencent.



Data Source: According to the EU released and organize

Figure 2 The number of listed companies and their R&D inputs

The R&D investment ranking released this time fully shows that the United States ranks first in 14 Internet, electronic information, semiconductor companies, and R&D expenditures of 157.797 billion euros, which effectively proves that Western companies attach importance to R&D factors. It also proves that the high-tech enterprises in the United States that are capital-intensive and technology-intensive are actually exporting technology and leading the industry when the net export of the industry is negative. The imported manufactured goods meet the needs of the people. Use R&D factors as an effective way for companies to maintain strong international competitiveness. However, from the other side, if the United States implements the industrial repatriation policy and relocates the manufacturing industry to the mainland and breaks the trend of economic globalization, then the territories of the world's semiconductor industry will undergo terrible changes.

4. Strategies to Enhance the International Competitiveness of China's Semiconductor Industry

4.1 To upgrade R&D investment to top international companies

Correctly understand the importance of R&D investment and encourage large companies to invest more than 20% in Intel, Qualcomm, a global top company, and continue to increase R&D investment as a percentage of sales. Encourage SMEs to align with large domestic companies and continue to increase the proportion of R&D to more than 10%. A high level of investment in the short-term will cause the company's liquidity shortage and profit reduction. However, taking a long-term perspective, domestic semiconductor companies will still have enough time for self-updating and innovation. The continuity of R&D investment will help encourage the long-term development of R&D personnel of enterprises, which will be beneficial to the improvement of product yield. At present, the semiconductor industry is facing a gentle period of Moore's Law, which is the window for corporate R&D. The capital market encourages more industry unicorn companies to expand their financing channels, and will greatly benefit the development of corporate technology and standards and a higher level of R&D strength in the capital adequacy phase.

4.2 To grasp the opportunity of industrial transfer and speed up the introduction of talent

The composite growth rate of the IC industry in China has reached 20%, which is much higher than 6.5% in the same period in the global market. CAGR After 2000, the semiconductor industry

chain formed the third shift, which was expanded from mainland China, Japan and South Korea to the mainland of Taiwan. The theme of ISSCC in 2017 is Intelligent Chips for A Smart World. From this we can see that the Internet of things and artificial intelligence are the future development direction of integrated circuits. The new growth points of semiconductor in the future will mainly come from applications such as Internet of things, intelligent cars, VR/AR, 5G, artificial intelligence and so on. In the era of Internet of things, semiconductor products will go deep into every aspect of life, and then it will be particularly important for the cultivation of high technology talents. After 2016, with the reduction in the number of high quality semiconductor companies overseas, the difficulty of mergers and acquisitions is more difficult. To break through the difficulty of the chip process must depend on the construction of the talent team. We can introduce high technology talents from overseas, establish cooperation model with universities and train senior talents, and attract talented people by good treatment.

4.3 To rely on the advantage of industrial fund to train the leading industry

After the establishment of the National IC industry fund, all localities have taken positive measures to follow up, and the local version of industrial funds and industrial alliances have been established successively. Although the capital market is not the biggest problem at present, it is an indisputable fact that the core technology is lagging behind the top companies for about 2 years. In each of the industrial migration, there will be a large number of international leading enterprises. The government has played an important role in the development of semiconductor industry, especially in the early stage of industrial development, and has given great support to the development of semiconductor industry in the United States and Japan. China University of Guangda Securities Research Report shows that the national fund for the first phase of the local integrated circuit industry investment fund (including preparation) reached 514 billion 500 million yuan, plus its own 138 billion 700 million yuan, with a total of up to 653 billion 200 million yuan. The scale of the two periods is estimated at 1500-2000 billion yuan. According to the prying ratio of 1:3, the scale of social funds prying is about 4500-6000 billion yuan. The overall scale of the first plus two periods is expected to exceed 1 trillion yuan, which will provide new impetus for the development of the industry. In the next few years, the domestic IC industry will develop rapidly in the next few years. Although mainland enterprises are relatively young, they should be on the threshold of policy and capital draught, and domestic manufacturers should form scale and cluster effect as soon as possible.

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