Quantification Evaluation of Technical Innovation Capabilities of China's Large and Medium-Size Industrial Enterprises

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Abstract

Since the beginning of 21st century, the process of industrialization in China has been further accelerated and the general scale of industry has been enlarged continuously. The industrial production capacity has been continuously strengthened and the scale of some products has taken the lead internationally. In the process of industrialization, scientific R&D and technical innovation activities carried out by large and medium-size enterprises (hereinafter referred as LMEs) have gradually become the fundamental impetus and source to promote the rapid and sustainable development of industry. Based on the data released by National Bureau of Statistics, this article makes a full and systematic quantification research on the technical innovation capabilities of China's LMEs, and objectively evaluates the level of technical innovation capability of China's LMEs by using indicators for science and technology in comparison with corresponding figures of foreign developed countries.

1 Introduction

National scientific competitiveness, as mainly composed of technical innovation capabilities of enterprises, is becoming the core and impetus of national competitiveness in 21st century. Therefore, it becomes an urgent need for governmental competent scientific departments at all levels to guide enterprises to attach more importance to R&D and increase R&D funding, support enterprises to become the main body of scientific innovation, promote reasonable distribution of innovative resources, raise the efficiency of national scientific funding, provide favourable environment for the technical innovation of enterprises, and gradually lift national scientific competitiveness as a whole. At the same time, it also gradually becomes common concerns for the competent department, the industry and the academia to lucubrate and develop systems to monitor and evaluate the technical innovation capabilities of enterprises and timely carry out the systems afterwards.

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industrial production capacity has been continuously strengthened and the scale of some products has taken the lead internationally. In the process of industrialization, scientific R&D and technical innovation activities carried out by LMEs have gradually become the fundamental impetus and source to promote the rapid and sustainable development of industry. Based on the up-to-date data released by National Bureau of Statistics of China (hereinafter referred as NBSC), this article makes a full and systematic quantification research on the technical innovation capabilities of China's LMEs, and objectively evaluates the level of technical innovation capability of China's LMEs by using indicators for science and technology in comparison with corresponding figures of foreign developed countries.

2 Method

Of all the definitions of "innovation", technical innovation as mentioned in this study refers to a process from idea to realization, which includes R&D, design, experiments, market investigation, test-marketing, etc. As long as the "process" is completed, innovation is fulfilled (NBSC).

LMEs are enterprises which have more than 300 employees, have sales income of more than RMB 30 million and total assets of more than RMB 40 million, as defined by NBSC.

Basically, data are collected and processed by industries, as catalogued by NBSC. Comparisons are made between industries and by time series.

3 Data

All the data are from public source from NBSC, including publications and online database[5].

In a parallel study which focuses on listed companies, we also used other sources like the annual reports of listed companies.

4 Results

4.1 General situation of technical innovation activities of LMEs

(1) Distribution of technical innovation activities

In 2005, there were 6,874 LMEs with technical innovation activities in China, accounting for 24.1% of all the LMEs. Of them, about 55.7% of large-sized enterprises carried out technical innovation activities; however, only 21.0% of medium-size enterprises did so.

Manufacturing sector is an industrial cluster in which technical innovation activities are most centralized. In 2005, there were 6,476 LMEs in China's manufacturing sector with such activities, accounting for 94.2% of the total. However, the distribution of technical innovation activities carried out in various industries of manufacturing is uneven. Technical innovation activities in eight industries constituted the main body of technical innovation activities in manufacturing sector (i.e. manufacture of communication equipment, computers and other electronic equipment, manufacture of electrical machinery and equipment, manufacture of transport equipment, manufacture of general purpose machinery, manufacture of raw chemical materials and chemical products, manufacture of special purpose machinery, manufacture of medicines, and manufacture of textile), and the number of enterprises that carried out technical innovation activities reached 4,372, accounting for 67.5% of all enterprises in manufacturing sector that carried out such activities.

By analyzing the proportions of enterprises that carried out technical innovation activities by industries, Table 1 shows that industries with highest technical innovation level are manufacture of medicines, manufacture of tobacco, manufacture of special purpose machinery, manufacture of measuring instruments and machinery for cultural activity and office work, manufacture of transport equipment, manufacture of general purpose machinery, manufacture of electrical machinery and equipment, and manufacture of communication equipment, computers and other electronic equipment, with the proportion basically exceeding 30%, and the proportion for manufacture of medicines even reached 55.1%.

[5] cf. http://www.stats.gov.cn/tjsj/qtsj/index.htm

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Table 1: Technical innovation activities in manufacturing sector (Top 8 industries with highest technical innovation levels)

Name of industry	Proportion of enterprises that carry out technical innovation activities (%)
MoM	55.1
MoT1	44.1
MoS	43.0
MoM	38.0
MoT2	37.7
MoG	36.7
MoE	35.2
MoC	33.2

MoM1-Manufacture of medicines;
MoT1-Manufacture of tobacco;
MoS-Manufacture of special purpose machinery;
MoM2-Manufacture of measuring instruments and machinery for cultural activity and office work;
MoT2-Manufacture of transport equipment;
MoG-Manufacture of general purpose machinery;
MoE-Manufacture of electrical machinery and equipment;
MoC-Manufacture of communication equipment, computers and other electronic equipment.

(2) Establishments of scientific institutions by enterprises

By 2005, 23.7% of the LMEs in China established S&T institutions, and its accumulated number reaches 9,350. The average expenditure for S&T activities was RMB 8.2 million for every institution.

"State-accredited enterprise technical center" is generally the R&D organization with relatively higher scientific and technical research level, which has an important leading role in the construction of national innovation system and enterprise's innovation capability. By 2005, there were totally 361 State-accredited enterprise technical centers, a larger proportion of which located in eastern provinces and cities.

4.2 Analysis of R&D activities carried out by LMEs

(1) R&D personnel

In 2005, there were totally 760,000 R&D personnel in China's LMEs, accounting for 2.0% of all employees. Comparing with the situation of past years, the size of R&D personnel basically shows a gradually rising trend, especially in 2005. But the growth speed in recent years has slowed to some extent: the average growth rate of R&D personnel from 1996 to 2000 was 7.6%, while this figure from 2001 to 2004 decreased to 4.8% (Figure 1).

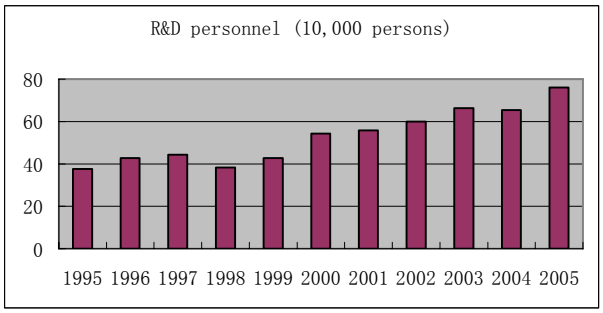

Figure 1: R&D personnel in LMEs, 1995-2005

The R&D personnel of China's LMEs mostly concentrated in the manufacturing sector, accounting for 88.1%. Thereinto, the sizes of R&D personnel in manufacture of communication equipment, computers and other electronic equipment, manufacture of transport equipment, manufacture of general purpose machinery, manufacture of electrical machinery and equipment, processing of ferrous metal ores, manufacture of raw chemical materials and chemical products, manufacture of special purpose machinery were the biggest, and the total R&D personnel in these seven industries accounted for 70.6.% of R&D personnel in entire manufacturing sector.

(2) R&D expenditure

In 2005, R&D expenditure of China's LMEs was RMB 125.03 billion. Comparing with the situation of past years, R&D expenditure basically shows a rising trend, and the growth rate accelerated considerably in recent years (Figure 2). The average growth rate of R&D expenditures from 1996 to 2000 was 20.1%, and this figure increased to 28.7% from 2001 to 2005.

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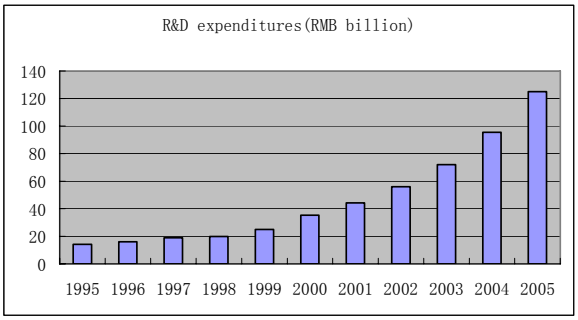

Figure 2: R&D expenditures of LMEs, 1995-2005

As to the source of R&D expenditures, the R&D expenditures of LMEs mainly come from enterprises themselves in recent years. The proportion of enterprise investments is increasing year after year, which accounted for 94.5% of the total R&D expenditures in 2005. Governmental fund has increased in real terms over the past decade, but its proportion in R&D expenditures is decreasing, and governmental funds only accounted for 3.6% in 2005 (Table 2).

Table 2: Composition of R&D expenditures sources of LMEs, 2000-2005

Year	R&D expenditure (RMB billion)	Governmental funds (%)	Enterprise funds (%)
2000	35.36	6.3	88.7
2001	44.23	4.9	91.3
2002	56.02	5.0	91.2
2003	72.08	4.0	92.9
2004	95.44	3.7	94.8
2005	125.03	3.6	94.5

R&D activities include such three types of activities as fundamental research, application research and experimental development. For China's LMEs, experimental development activity is the main body of R&D activities. In 2005, the expenditures of LMEs used for fundamental research and application research only accounted for 5.8% of the total R&D expenditures, while the expenditure of experimental development accounted for the most part of R&D expenditures.

In 2005, R&D expenditures invested by LMEs in manufacturing sector of China were RMB 118.4 billion, accounting for 94.7% of the expenditures of all LMEs. In manufacturing sector, the R&D expenditures invested by manufacture of communication equipment, computers and other electronic equipment, manufacture of transport equipment, processing of ferrous metal ores, manufacture of electrical machinery and equipment, and manufacture of raw chemical materials and chemical products were the most, and the R&D expenditures of these five industries accounted for 65.9% of the R&D expenditures of entire manufacturing sector.

R&D intensity, defined as the proportion of R&D expenditures to sales, is generally low in China's LMEs (Table 3). The average R&D intensity for all the LMEs was only 0.76% in 2005 and it was 0.86% for LMEs in manufacturing sector. Manufacture of special purpose machinery had the highest R&D intensity, namely 1.61%. Business R&D intensities in western developed countries are usually between 2%～5%, with an average of 2.2% for OECD countries[6].

Table 3: R&D intensity of industries in manufacturing sector (Top 10 with highest R&D intensity)

Industry	R&D intensity (%)
MoS	1.61
MoM1	1.52
MoT2	1.39
MoE	1.39
MoG	1.28
MoC	1.18
MoM2	0.92
MoR1	0.90
MoR2	0.85
MoW	0.80

MoS-Manufacture of special purpose machinery;
MoM1-Manufacture of medicines;
MoT2-Manufacture of transport equipment;

[6] Cf. http://puck.sourceoecd.org/vl=16824148/cl=40/nw=1/rpsv/sti2007/a-5.htm

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MoE-Manufacture of electrical machinery and equipment;
MoG-Manufacture of general purpose machinery;
MoC-Manufacture of communication equipment, computers and other electronic equipment;
MoM2-Manufacture of measuring instruments and machinery for cultural activity and office work;
MoR1- Manufacture of raw chemical materials and chemical products;
MoR2- Manufacture of rubber;
MoW- Manufacture of wood, bamboo, rattan, palm.

(3) Analysis of R&D project expenditure

In 2005, R&D project funds of China's LMEs were RMB 94.9 billion, accounting for 75.9% of the total R&D expenditures. The number of R&D projects carried out in 2005 was 34,979, and the average expenditure for each project was about RMB 2.7 million. The number of R&D project personnel involved was 525,229, with average R&D project expenditure per person of RMB 181,000.

From the perspective of project source, self-selected scientific projects by enterprises accounted for 78.3% of all R&D projects, and national scientific projects and local projects accounted for 6.3% and 8.2% respectively. The numbers of scientific projects from consignment of other enterprises or foreign countries only accounted for 3.9% and 1.3% respectively (Figure 3).

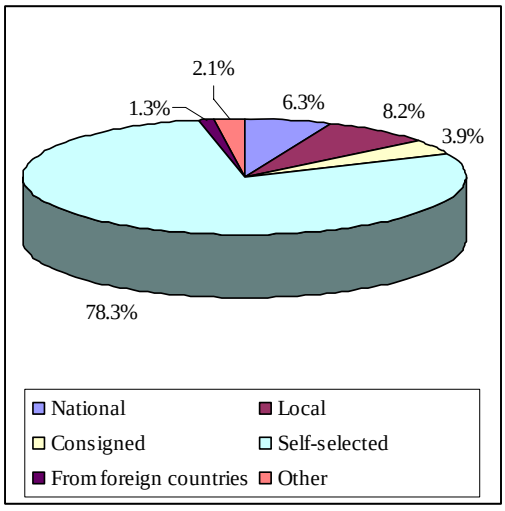

Figure 3: Distribution of R&D project sources

Technical and economic targets of R&D projects include: developing entirely new product, adding functions to original product, raising functions of product, raising labor productivity, reducing energy consumption, saving raw materials and reducing environmental pollution etc. Thereinto, 49.1% of R&D projects targeted to develop entirely new product, 14.5% of projects to raise functions of product, 10.2% to raise labor productivity, and 8.3% to add functions of original product (Figure 4).

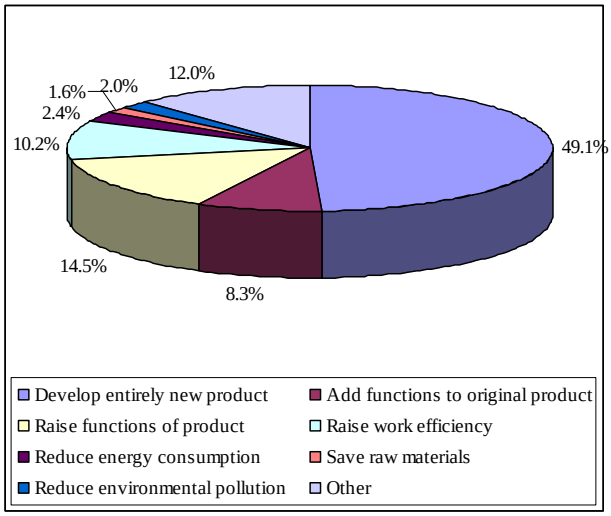

Figure 4: Technical and economic targets of R&D projects

4.3 Analysis of technical innovation output of LMEs

Technical innovation output is one of the most important factors to evaluate technical innovation capability, and patent output and new product sale are most commonly used two evaluating indicators.

(1) Production and sale of new product

In 2005, the production and sale of new product of China's LMEs increased by great amplitude comparing with that in 2004, realizing RMB 2538.2 billion production value and RMB 2409.7 billion sales income, with RMB 553.9 billion for export. As for output benefit, the proportion of sales income of new products in sales income of all products for recent five years

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remained at about 15%. The export of new products increased considerably, and the proportion of export in sales income of new products exceeded 20% once again.

In 2005, LMEs in manufacturing sector realized RMB 2507.4 billion production value of new products and RMB 2380.4 billion sales income, accounting for 98.8%, 98.8%of all LMEs respectively. The sales incomes of new products from such six industries as manufacture of communication equipment, computers and other electronic equipment, manufacture of transport equipment, manufacture of electrical machinery and equipment, processing of ferrous metal ores, manufacture of general purpose machinery, and manufacture of raw chemical materials and chemical products accounted for 73.9% of new products incomes of the whole manufacturing sector.

(2) Patent application and ownership

In 2005, China's LMEs filed 55,271 patent applications, with 30% year-on-year increment. Of the three kinds of patent applications in China, 18,292 were patents for invention, increasing by about 31.5%. The proportion of applications of patent for invention for recent five years showed a rising trend year after year, reaching 33.1% in 2005 (Figure 5). This made the number of ownerships of patent for invention by LMEs reach 22,971.

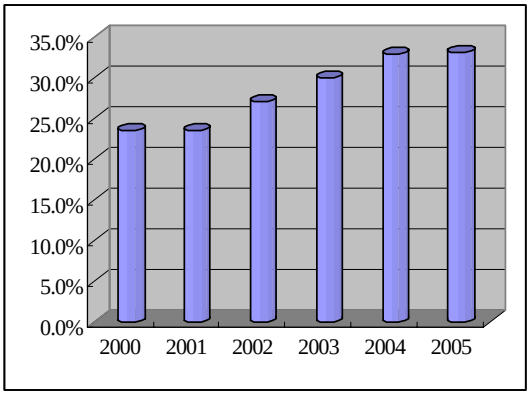

Figure 5: Proportion of application of patent for invention by LMEs (2000-2005)

Patent applications by LMEs mostly concentrated in manufacturing sector. LMEs in manufacturing sector filed 53,843 patent applications, in which number of patents for inventing was 17,983, accounting for 97.4% of total patent applications by LMEs. The patent applications of such six industries as manufacture of communication, computer and other electric equipment, manufacture of electrical machinery and equipment, manufacture of transport equipment, manufacture of general purpose machinery, manufacture of special purpose machinery, and manufacture of medicines accounted for 70.0% of that of entire manufacturing sector. Manufacture of medicines had the highest level of patent for invention, with proportion of applications of patent for invention reaching 61.3%.

4.4 Analysis of technical introduction and assimilation of LMEs

In 2005, China's LMEs expended a total of RMB 29.7 billion on introducing foreign technologies, RMB 6.9 billion on assimilating and absorbing foreign technologies, and RMB 8.3 billion on purchasing domestic technologies. Comparing with that in 2004, the expenditure on introducing foreign technologies decreased to some extent, but the expenditure on assimilating and absorbing foreign technologies increased by 27.7%. However, the ratio of expenditure on assimilating and absorbing technologies to that on introducing technologies was still relatively low, which was 0.23:1, while this ratio of enterprises in South Korea and Japan usually reached 5:1 to 8:1. Manufacturing enterprises were still the main body of technical introduction, and expended RMB 28.8 billion on introducing foreign technologies in 2005, accounting for 97.0% of the expenditure on introducing foreign technologies by LMEs.

As shown in Table 4, the expenditures on technology assimilation and absorption were far less than that on technology introduction. The ratios of expenditure on technology assimilation and absorption to that on technical introduction in some industries were less than 20%, such as manufacture of transport equipment, processing of ferrous metal ores, processing of non-ferrous metal ores and processing of petroleum, coking, processing of nuclear fuel. Manufacture of non-metallic mineral products and manufacture of medicines had the highest ratio of 68.5% and 97.6%, respectively.

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Table 4: Expenditure on technical introduction and assimilation by LMEs (Top 10 industries with highest expenditure on assimilating and absorbing technologies)

Industry	A	B	A/B (%)
MoC	7,593.8	2,334.4	30.7
MoT2	4,404.4	802.9	18.2
MoE	1,444.7	596.8	41.3
PoF	4,872.1	553.7	11.4
MoR1	1,954.8	430.2	22.0
MoM1	358.2	349.7	97.6
MoG	1,356.3	335.3	24.7
MoN	198.4	135.8	68.5
PoN	1,318.4	117.1	8.9
PoP	897.7	103.4	11.5

A: Expenditure on introducing technologies (RMB million);
B: Expenditure on assimilating and absorbing technologies (RMB million).
MoC-Manufacture of communication equipment, computers and other electronic equipment;
MoT2-Manufacture of transport equipment;
MoE-Manufacture of electrical machinery and equipment;
PoF- Processing of ferrous metal ores;
MoR1- Manufacture of raw chemical materials and chemical products;
MoM1-Manufacture of medicines;
MoG-Manufacture of general purpose machinery;
MoN- Manufacture of non-metallic mineral products;
PoN- Processing of non-ferrous metal ores;
PoP- Processing of petroleum, coking, processing of nuclear fuel.

5 Discussion

(1) Actively carrying out scientific research and development and technical innovation activities provides groundwork and impetus to sustainable development for enterprises. Statistics data reflects that China's LMEs are not actively engaged in carrying out technical innovation activities. Only less than 1/4 of LMEs have carried out such activities, and this data is obviously low comparing with situation that enterprises in foreign developed countries commonly attach more importance to technical innovation activities. Manufacturing sector is the most centralized industry cluster that carries out technical innovation activities, accounting for 94.2% of all LMEs that have done so. The performance of manufacture of medicines is notable, the aforesaid proportion of which even reaches 55.1%. This seems reasonable considering that medicines manufacturing industries of other countries in the world are also generally paying more attention to R&D and technical innovation comparing with other industries.

(2) Scientific institution in enterprise is the basic organizational form of enterprise that carries out technical innovation activities and the important carrier that optimizes the allocation of various scientific resources. Enterprises with scientific institutions only account for 23.7% of all LMEs, which is every unfavorable for building up a stable professional scientific team that carry out long-term key problem tackling research and raising enterprises' key technical R&D capabilities and core competitiveness. It is to be noticed that the although the number of scientific institutions established by large-sized enterprises is relatively small, only accounting for 29.5% of all large-medium industrial enterprises, the personnel for S&T activities and expenditures on S&T activities of them account for 58.6% and 66.2% respectively.

(3) R&D expenditures are the material base and source for enterprise to carry out technical innovation activities. In recent years, both R&D personnel and R&D expenditure of China's LMEs are showing a stably rising trend. However, R&D intensity is still rather low, and even for large and medium manufacturing enterprises with higher technological level, the intensity of R&D expenditure is only 0.86%, far behind that of enterprises in foreign developed countries.

(4) The R&D expenditures of China's LMEs are mainly self-owned capital. In 2005, enterprise capital accounted for 94.5% of all R&D expenditures. Currently, 30% of scientific funds in developed countries are used to support enterprises, while in China over 90% of such funds are expended on scientific research institutions and universities and colleges, which accounts for the decreasing proportion of governmental funds in R&D expenditures of enterprises.

As to the goals of R&D activities to be carried out, China's LMEs give more priority to ex-

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perimental development research, the expenditures for which account for most part of R&D expenditures. This situation is very different from enterprises in foreign developed countries that pay more attentions to basic research. Although enterprises have begun to attach more importance to basic research and application research in recent years, their proportion in R&D expenditures is still low. And at the present time, the technical innovation activities carried out by China's LMEs are basically in-house R&D, and cooperative R&D with other enterprises, especially foreign enterprises and institutions are rather rare. Technical and economic targets of R&D projects are mostly to develop entirely new products and add functions to original products.

(5) Actively carrying out scientific R&D activities has directly promoted continuous growth of technical innovation output of enterprises. In recent five years, for China's LMEs, both the proportion of sales income of new products in that of all products and the proportion of export amount of new products in sales income of new products have realized growth by large amplitude. At the same time, the quantity of patent applications of China's LMEs and the proportion of applications of patent for invention are showing a rising trend.

(6) Technology acquaintance by enterprise is necessary for the development of enterprise. Internally technology acquaintance by enterprise is mainly realized through carrying out R&D activities, while externally technology acquaintance is mainly realized through introducing foreign technologies, assimilating and absorbing them and then re-creating. At present, the expenditures of LMEs on introducing foreign technologies decrease to some extent, while the expenditures on assimilating and absorbing technologies are gradually increasing. However, the ratio of expenditures on assimilating and absorbing technologies to that on introducing technologies is still rather low（only 0.23:1）, far lower than the corresponding indicator of enterprises in South Korea and Japan.

It is very much appreciated that someone has relevant data of countries other than china and would share them with the authors, so that more detailed international comparisons can be made.

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