Winter 12-4-2009

A Technological Catching-Up Model of Modularized Industry in Developing Countries

Yi-Bo Lu

Jing-Qin Su

A TECHNOLOGICAL CATCHING-UP MODEL OF MODULARIZED INDUSTRY IN DEVELOPING COUNTRIES

Yi-Bo Lu[1], Jing-Qin Su[2]
School of Management
Dalian University of Technology, Dalian, China
[1]luyibo@dlut.edu.cn; [2]jingqin@dlut.edu.cn

Abstract

This article discussed the technological catching-up problem of modularized industry in developing countries. Firstly, this article analysed the relationship between technical level, technology learning capability, technological innovation capability and technological capability; then, stated that the technological catching-up of modularized industry in developing countries is the integration of catching-up in technical level and technological capability. After comparing the developing mode of modularized industries in developing countries with that in developed countries, this article puts forward a technological catching-up model of modularized industry in developing countries.

Keywords: modularized industry; technological catching-up; technological capability; developing countries

Introduction

The 'absence' of key technology is the main obstacle of Chinese manufacturing industries. With the development of industrial modularization, it has become more difficult to obtain 'industrial key technology' for China. Therefore, research on technology development and technological capability cultivating of modularized industry is very important for China, to achieve industrial technology improvement and industrial upgrading.

Based on fundamental principle of modularity, this article stated the hierarchy characteristics of industrial technology. After analyzing the synergetic and dependant relationship among different technological hierarchies of modularized industry, this article pointed out that technology platform of modularized industry is the 'key module hierarchy'. Then, this article analyzed the relationship between technical level, technology learning capability, technological innovation capability and technological capability; and stated that the technological catching-up of modularized industry in developing countries is the integration of catching-up in technical level and technological capability. Finally, after comparing the technology development mode of modularized industries in developing countries with that in developed countries, this article puts forward a technological catching-up model of modularized industry in developing countries.

The development of technological hierarchy in modularized industry

Modularity is a procession of disaggregating a complex system into several interlinked sub-systems by certain rules (Masahiko, 2003). The core characteristics of modularity are: ① Independence of single module and interactions between modules in complex systems. ② Decomposed a complex system by modularization simplifies the interfaces of a system. Based on the widely used technology modularity in products design and manufacturing, industry modularization grew and developed. Industry modularization drives industry system hierarchy development, and further deepens the development of industrial technology system hierarchy.

So technology in modularized system can be divided into 'system technology hierarchy' and 'module technology hierarchy'. Module technology consists of key module technology and common module technology. System technology is the technology about system entire structure, design and coordination; it composes of structure technology, interface technology and standard technology. Modularity technology is a set of internal knowledge combination that helps modules implement their performance and achieve the requirements of systems.

Key modules are very important for the existence and development of whole modularized system. Key modules have the following three characteristics: ① Complexity of technology inside key modules is much higher; ② More interactions between key modules and other modules. Key modules have great influence to the whole systems. ③ Key module's function is the main function of super modules or the main body of super module's functions. Therefore, 'key module hierarchy' which includes key modules and interactions between key modules in modularized system, is the core of the whole system.

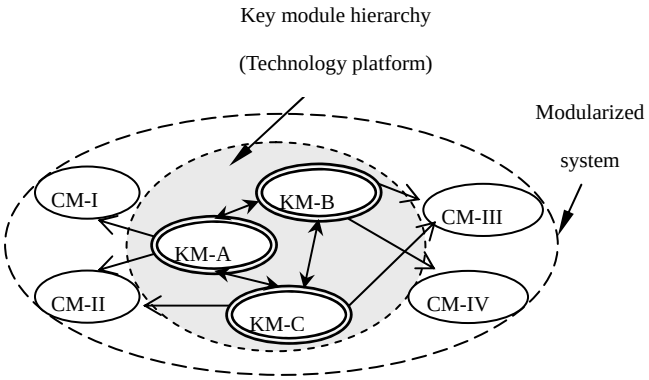

Figure 1. The hierarchy structure of technology in modularized system

Technology development of the whole modularized industry needs the synergetic development of each technology hierarchy. That is, technology in key module design hierarchy is the key of the technology platform; technology developing in other hierarchies mutually is based on technology in key module design hierarchy; as a result, the synergetic development for technology in the whole modularized industry is achieved.

Technological catching-up of modularized industry in developing countries

The technological catching-up of modularized industry in developing countries should achieve two kinds of catching-up, one is the catching-up in technical level, shorten the technology gap with developed countries; the other is the catching-up in technological capability, achieving the sustainable development of technological catching-up.

Through analyses the connotations of technological capability, technical level, and their relationships, this chapter discusses the synergetic development mode in developing countries and in developed countries respectively, and illuminates the technological catching-up mechanism of modularized industry in developing countries.

The connotations of technological capability, technical level and their relationships

Technological capability is the capability of obtaining advanced technology and information, creating new technology and knowledge, realizing technological diffusing, and increasing the storage of technology and knowledge (Wei & Xu, 1996). It has two sub-dimensions: technology learning dimension and technological innovation dimension. Technology learning is the learning activities through acquirement, learning and absorption from current technological system. Technological innovation is activities of introducing a new production, procession or service into market, realizing their economic benefits. Technological innovation is new technologies' creating and diffusing, the direct outcome and final destination is to improve the technical level. Technical level refers to the technological qualities, it has three dimensions: innovation, advancement and reliability.

Seen form the definitions above, technical level is 'stock conception', technological capability is 'incremental conception'. Technological capability can promote technical level through technology learning and technological innovation. So this article made a definition of the relationship between technological capability, technology learning capability, technological innovation capability and technical level as follows: technological capability is the integration of technology learning capability and technological innovation capability, are the first derivative of technical level. Technical level is a concave function. The main reason is the effect of "learn by doing" and "experience curves". Technology learning and technological innovation have a continuous improvement, and also the technological capability, so the improvement of technical level is accelerated.

The function of their relationships is as follows:

$$\begin{cases} TC(t) = \alpha TSC(t) + (1-\alpha)TIC(t) = LT'(t) \\ LT(t) = \int_t \alpha TSC(t) + (1-\alpha)TIC(t) = \int_t TC(t) \end{cases}$$

t is independent variable of time, $TC(t)$ is the function of technological capability, $TSC(t)$ is the function of technology learning capability, $TIC(t)$ is the function of technological innovation capability, $LT(t)$ is the function of technical level, $0 \le \alpha \le 1$.

The development mode of modularized industrial technology in developed countries

The development of modularized industry stems from the formation of technology platform. The stabilization of platform technology is the result of drastically competition between different technical standards and dominant designs. So in a long period, the platform technology will be stable, until a more advanced platform comes into being.

Seen form the dimension of technological modularization, the synergetic development of system technology, common module technology and key module technology is shown as figure 2 (TL refers to technical level). $A^1B^1D^1$ is the development track of key module technology (platform technology), $O^1B^1E^1$ is the development

track of system technology and common module technology.

Seen form the dimension of industrial organization modularization, the synergetic development of manufacturing technology and design technology appears a similar mechanism. Shown as figure 3, the development track of design technology is $A^2B^2D^2$, $O^2B^2E^2$ is the development track of manufacturing technology.

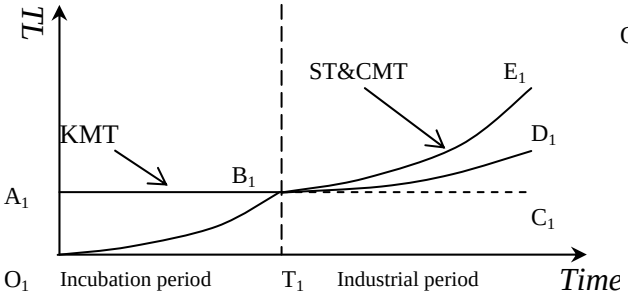

Figure 2. The synergetic development between system technology (ST), common module technology (CMT) and platform technology (Key module technology, KMT) in developed countries

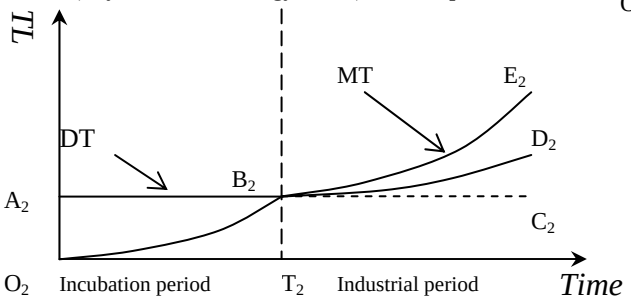

Figure 3. The synergetic development between manufacturing technology (MT) and design technology (DT) in developed countries

The development mode of modularized industrial technology in developing countries

The development of modularized industry in developing countries is under the condition of technology diffusing and global division of labor. So developing countries can learn system technology and common module technology through technology diffusing, and acquire manufacturing technology through global division of labor. The design technology in key module hierarchy-- platform design technology, which is in a form of 'technological black box', can't be learned or acquired through technology diffusing or technology purchasing. The design technology in key module hierarchy should be improved through industrial practices. So it is different from the 'key technology→peripheral technology' mode in developed countries, the development mode in developing countries is "peripheral technology→key technology".

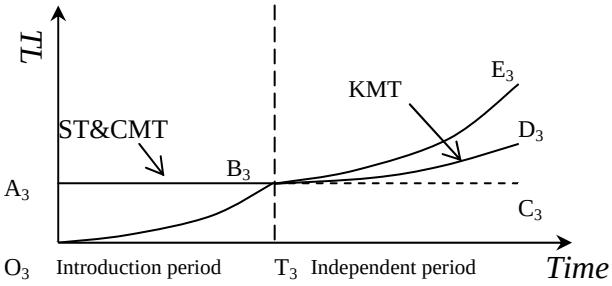

Figure 4. The synergetic development between system technology (ST), common module technology (CMT) and platform technology (Key module technology, KMT) in developing countries

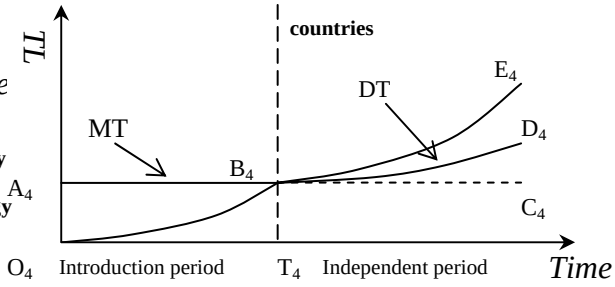

Figure 5. The synergetic development between manufacturing technology (MT) and design technology (DT) in developing countries

Seen from the dimension of industrial technology modularization, there is a similar synergetic development between system technology, common module technology and key module technology (platform technology). Shown as figure 4, the development track of key module technology is $O^3B^3D^3$, $A^3B^3E^3$ is the development track of system technology and common module technology.

Seen from the dimension of industrial organizational modularization, it appears a similar mechanism of synergetic development between design technology and manufacturing technology. Shown as figure 5, the development track of design technology is $O^4B^4D^4$, $A^4B^4E^4$ is the development track of manufacturing technology.

A technological catching-up model of modularized industry in developing countries

'Creative destruction' is the main obstacle of technological catching-up in modularized industries faced by developing countries. The leaping development of 'technology platform'--the fundamental change of technology platform caused the radically changes in the technological system of modularized industry. Based on A-U Model, the changes of technology platform need a long time,

once happen, there is a radically change in the whole industry. The direct result of the upgrade of technology platform is the totally invalidation of old platform, and the technical level based on old platform will lost totally. Figure 6 describes the technological catching-up of modularized industry in developing countries under different technology platforms. $A^*B^*D^*$ is the development track of system technology, common module technology and manufacturing technology, $O^*B^*C^*$ is the development track of design technology of platform (* show the different development stage of platform).

In the initial O^I, the platform design technical level of developing countries is zero, the technology gap is O^IA^I(the platform design technical level of developed countries is over A^IB^I). In stage I, the development track of system technology, common module technology and manufacturing technology is $A^IB^ID^I$, the development track of platform design technology is $O^IB^IC^I$. Before B^I, the modularized industry is in the introduction period, the level of system technology, common module technology and manufacturing technology is over A^IB^I, the level of platform design technology is promoted to the level of A^IB^I through industrial practice, and achieve synergic development between different hierarchies. After B^I, the development of modularized industry came into independent development period, the technology innovations in other hierarchies of modularized technology system, pull the development of innovation in platform design technology, the level of platform design technology advanced to B^IC^I. At the end of stage I, technology gap reduce to C^IA^{II}.

When the modularized industry developed form stage I to stage II, because the effect of 'creative destruction' in platform technology, the technical level based on old platform is totally invalided. At the jumping-off point of stage II--O^{II}, the technical level of modularized industry in developing country reduce to 0. There is a totally loss in technical level in developing countries under new platform, but the technological capability cultivated in stage I has no loss, it continued developing in form of technology learning capability and technological innovation capability in stage II. There is a similar development track in all of the hierarchies in modularized industries, and we only illuminate the development track of platform design technology. In introduction period, the growth of technological capability is the improvement of technology learning capability, technological innovation capability is stable; when stepped into independent development period, the growth of technological capability is the improvement of technological innovation capability, technology learning capability is stable. The growth of technology learning capability and technological innovation capability has the characteristics of continuous; it can't loss for the sake of the upgrade of platform (Shown as figure 7).

In stage II, technology learning capability in introduction period is higher than that in stage I. The growth rate of platform design technology is accelerated, so developing countries can achieve the synergetic development in different technology hierarchies in a short time, the length of introduction period is shorten. During independent period, the growth rate of system technology, common module technology and manufacturing technology is also higher than that in stage I. So the pulling effect is distinctly increasing. So at the end of stage II, the technology gap reduces to $C^{II}A^{III}$. Through several upgrade of technology platform, developing countries should achieve technological catching-up in stage N. At the ending point of stage N-1--O^N, the technology gap is 0, developing countries achieve the technological catching-up.

The function of the continuous of TC is as follows:

$$\begin{cases} SMTL'_{(\mathrm{I})-}(B^{\mathrm{I}}) = SMTL'_{(\mathrm{II})+}(O^{\mathrm{II}}) \\ SMTL'_{(\mathrm{I})}(D^{\mathrm{I}}) = SMTL'_{(\mathrm{II})+}(B^{\mathrm{II}}) \\ SMTL'_{(\mathrm{II})-}(B^{\mathrm{II}}) = SMTL'_{(\mathrm{III})+}(O^{\mathrm{III}}) \\ SMTL'_{(\mathrm{II})}(D^{\mathrm{II}}) = SMTL'_{(\mathrm{III})+}(B^{\mathrm{III}}) \\ \cdots \\ SMTL'_{(N-1)-}(B^{\mathrm{N-1}}) = SMTL'_{(N)+}(O^{\mathrm{N}}) \\ SMTL'_{(N-1)}(D^{\mathrm{N-1}}) = SMTL'_{(N)+}(B^{\mathrm{N}}) \end{cases}$$

$$\begin{cases} PTL'_{(\mathrm{I})}(C^{\mathrm{I}}) = PTL'_{(\mathrm{II})+}(B^{\mathrm{II}}) \\ PTL'_{(\mathrm{II})}(C^{\mathrm{II}}) = PTL'_{(\mathrm{III})+}(B^{\mathrm{III}}) \\ \cdots \\ PTL'_{(N-1)}(C^{N-1}) = PTL'_{(N)+}(B^{N}) \end{cases}$$

$SMTL_{(n)}(T)$ is the function of the level of system technology, common module technology and manufacturing technology in stage n; $PTL_{(n)}(T)$ is the function of the level of platform design technology in stage n.

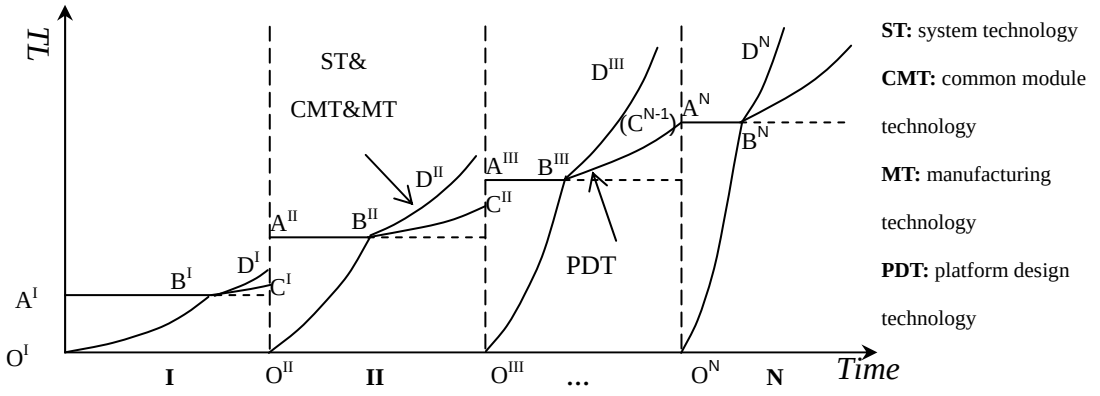

Figure 6. Sketch of technical level catching-up of modularized industry in developing countries

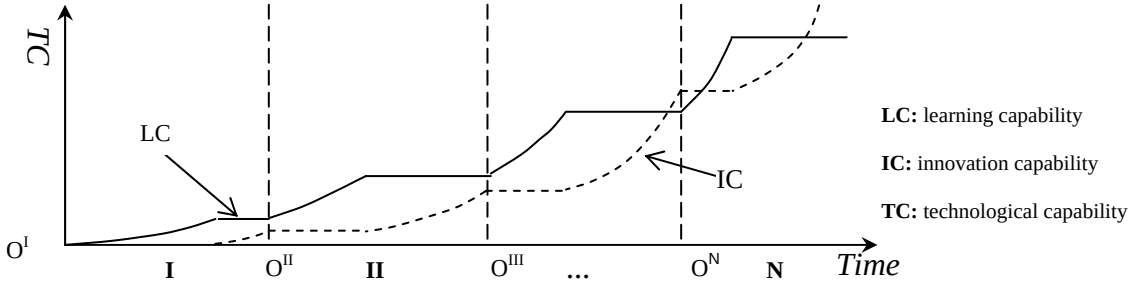

Figure 7. Sketch of technological capability catching-up of modularized industry in developing countries

Conclusions

This article explained the synergetic development and mutual growth of different hierarchy technologies in modularized industry. The main conclusions are as follows:

(1) The development of industrial modularization drives the hierarchy development of industrial technology. There are mutual developments among different hierarchies of the whole technology system in modularized industry, which include mutually developed system technology, common modular technology and platform technology, design technology and manufacturing technology.

(2) The technology development mode of modularized industries in developing countries is different from that in developed countries. The technology development mode of modularized industries in developed countries is the synergetic development of 'key technology → peripheral technology'; while the technology development mode in developing countries is the synergetic development of 'peripheral technology → key technology'.

(3) There are two parts of technological catching-up in developing countries--technical level catching-up and technological capability catching-up. Technological capability is the driving force of the development of technical level. Technical level's catching-up of modularized industry in developing countries is discontinuous. Technological capability grows based on R&D system, and is sustainable.

(4) Through a theoretical analysis of technological catching-up of modularized industry, we can see that the technology catching-up of modularized industries in developing countries should start from a certain hierarchy platform. It should not to pursue costly advanced technology platform. In advanced technology platform, the sustainable growth of technological capability makes the introduction period getting shorter and the independent development period getting longer; industrial technology capability is getting improved. Through several platforms of modularized industry updating, the modularized industry in developing countries achieves the industry technological catching-up gradually.

References

[1] Baldwin, C. Y., Clark, K. B.，1997, Managing in an age of modularity [J], Harvard Business Review, 75, pp 84-93

[2] Richard N. Langlois, Modularity in technology and organization [J], Journal of Economic Behavior and Organization, 2002.49:19-37