

## NEW WAVES OF INDUSTRIAL REVOLUTION FROM BREAK-THROUGH ACHIEVEMENTS OF SCIENCE AND TECHNOLOGY

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**Abstract:**

*Global process of innovations is continuously under strong implementation during recent decades where science and technology (S&T) super powers and transnational economic agglomerations play dominating roles. Break-through achievements in state-of-the-art technologies have created new industries and new models of development as well as shifted intensively global economic structure. Facts collected and interpreted in this paper show that science-technology make appear new waves of an industrial revolution, even a new industrial revolution. The world's economic cooperation and competition are still characterized by dominating advantages of nations and economic groups which hold key advanced technologies.*

*Efforts focused on in-depth and global studies of S&T development trends in the world to be adapted to fast changing situations would help us to choose priority orientations and scopes, and right partners for cooperation in field of S&T. These moves will make us over-pass challenges and take advantages of available opportunities, enhance S&T positions in development process of the country.*

**Keywords:** *New technology; R&D investment trend; New technological revolution.*

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International finance crisis has led to large adjustments and changes in economic structures of the world. In 2012, the world's economy continuously intensified adjustments of development strategies, from level of national interests to strategies of business competition between

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transnational groups all of which promoted fast development of new technologies and new trade models. This trend accelerated the global S&T revolution and led to a new industrial revolution.

### **1. R&D investments by enterprises steadily increase and make appear new trends**

Despite the recession of global economy and the slow recovery process coupled with uncertainties during recent years, and globally the great impacts are not seen from all of these to the growth of transnational groups and high tech industries. R&D investments by enterprises in global scale keep on increasing trends and create new features.

#### ***1.1. R&D investments by enterprises in global scale keep on increasing trends***

By October 2012, the World Economy Perspective Report made by IMF indicates that the world economic growth rate by 2012 is 3.3%. In this global figure of growth, the part of emerging and developing countries are 5.3% and the growth rate of China, India, Russia and Brazil experiences a slow down. The growth rate of developed nations is maintained at level of 1.3% including the USA with 2.2% and the shrinking Eurozone with 0.4%. Impacts from the world's economic recession to R&D investments and innovations by enterprises are observed large. However, R&D investments by transnational groups by 2012 still hold increasing trends. According to "Industrial News Daily", in 2012, R&D investments by Japanese enterprises hold on the increasing rates where the ones of car production and pharmaceutical sectors have the highest margins of rates and the ones of environment and energy are highly remarked. Investigations by EU Commission for European industrial sectors show that during 2012-2014 period the annual R&D investment growth rate of European enterprises is averagely 4%. Butler Memorial Research Institute of the USA made a forecast that the R&D investment rate of US enterprises gets the highest scale expected to be US\$279.6 billion making a growth of 3.75% compared to the same period of the previous year. "S&T and Economic Perspectives Report" made by OECD in 2012 also shows that the R&D investment rates by Chinese, Indian and South Korean enterprises hold on an increasing rate and a high ranking position.

#### ***1.2. Impacts from the world's economic recession to transnational groups and high tech industries***

It is possible to say that the impacts from the world's economic recession to R&D activities and benefits of transnational groups are not so much high as

guessed by many observers. The US magazine “Health”, by July 2012, provided the evaluation of the total turnover of the world’s top 500 companies at US\$29,400 billion making a growth of 13.3% compared to the same period of the previous year, and their benefits were US\$16,300 billion making a growth of 6.7% compared to the same period of the previous year previous. In a global context of the world’s economic recession, high tech industries yet hold on strongly increasing trends. Related statistic figures show that in 2012 the scale of new materials industry markets of the world was US\$1,000 billion making a growth of about 20% compared to the same period of the previous year, the scale of Internet networking experienced an annual growth rate of about 25%, the world market scale of semiconductor industries (SIA) was US\$315 billion and forecast to be US\$318 billion by 2016 having the annual average growth rate of 4.8%. Butler Memorial Research Institute provides a forecast of increasing trends of R&D investments in some industrial sectors such as aerospace and defense, energy, information technologies and communication, chemical and material industries.

### ***1.3. Some new features in trends of R&D activities of high tech based enterprises***

*(1) Open models of research cooperation have become an important trend in R&D activities of high tech enterprises.* A US investigation shows that, by 2012, 81% of US high tech enterprises take part in certain activities for R&D cooperation. By 2012, the expenditures for high quality R&D by the world’s largest tabac producing company Pfizer had been reduced by about 20% but, instead of that, the company extended cooperation activities with big research organizations and implemented the new type of open cooperation. GlaxoSmithKline, Novartis, Pfizer, Lilly and others take part in “Structure Gene Alliance” to promote R&D activities for new drugs through the new type of open cooperation;

*(2) Higher speed of transfer of R&D centers from developed economies to the emerging economies.* By 2012, the transfer of R&D centers from USA, EU and Japan to emerging economies such as China, Brazil and India had been accelerated. For China, as example, by end of 2011, transnational groups had constructed in China more than 1,200 R&D centers and the figure is kept permanently accelerated. A report form McKinsey & Company shows that while R&D centers in pharmaceutical sector in USA and Europe have to close or to reduce their scale the Chinese ones take to start or to extend the scale at the similar speed;

*(3) Incubating of newly emerging industries in market orientation.* During recent years, many new technologies and new products appear in large

quantities. This leads to a birth of new industries and offers large development opportunities. Many large enterprises, especially multinational companies, continue to adjust their strategies for development of core technologies to take advantageous positions in the world's value chains. Japanese private companies, in addition to traditional industry sectors, increase their investments in other industry sectors such as environment, energy and nano technologies. Some sectors capable of bringing advantages and large benefits such as treatment of diseases, health care, low carbon technologies get considerable growth rates of investments. It is worth to note that multinational companies accelerate the M&A activities to get core technologies, to integrate resources and research forces and then to extend fast to new industries and new markets.

## **2. Changes of competition models of spearhead industries and technologies**

Strong development and push-up of application of high techs have deepened the global process of cooperation and arrangement. Innovations of applications and competition of values have become the specific features of development of spearhead technologies and high tech industries.

### ***2.1. Advantages of product manufacturing technologies get lower and gradually replaced by high tech services***

As developed nations, the USA and Europe are re-creating the competition advantages through the issue of the strategy "Re-industrialization". In 2012, the USA issued "National Strategic Program of Advanced Manufacturing", the UK issued "Strategy of High Value Manufacturing". It is possible to see, the "re-industrialization" of the above noted developed countries is based mainly on development of high added value manufacturing industries and products, and rich knowledge integrating services. Actually, many multinational companies specialized in manufacturing of high tech products continuously integrate and add values for their products. The linking of high techs and service technologies promoted the emergence of high tech services and make the world's sector of high tech services grow continuously. By 2012, the world's high tech services take a share of 20% of the sector of high tech industries and 30% of the sector of advanced services.

Spearhead technologies such as software and high tech services are passing fast development and bring opportunities and challenges for manufacturing industries. By early 2012, US Eastman Kodak, with over-130-year history, bankrupted and one the reasons of that was the attack from software industry and high tech technologies. Mark Anderson, famous US investor, in his paper

“Why software dominate the whole world” had indicated that actually the vocational practice is shifted to take software as basis of activities, and we are passing the time where an increasing number of enterprises now operate on basis of applied software and provide on-line services. Statistic figures show that, by 2011, the turnover from software sales of the world’s enterprises was US\$267 billion making a growth of 9.5% compared to the same period of the previous year. High benefits and huge space of development in sectors of software industries and high tech services also are reasons to promote the shift of development strategies of many enterprises and the re-positioning of competitive advantages. By 2001, Hewlett-Packard bought Autonomy, a UK software company, with a price higher than US\$10 billion with the main targets to revitalize its software industry and services. Traditionally strong Internet companies such as Google, Baidu, Tencent have also extended their business to the sector of software and services, communication service providing AT&T and Verizon turned to be software producing companies through their shift of business.

According to “Report of analysis of investment policies and consultation of in-depth studies of Chinese software industry”, in the first half of 2012, Chinese software industry gained a turnover from software services of volume of US\$10.988 billion making a growth of 26% compared to the same period of the previous year. By December 2011, “the 12<sup>th</sup> Five-year Master plan for development software industry and information technology services” by Ministry of Industry and Information puts targets to achieve, by 2015, the turnover of US\$4,000 billion making an annual average growth of more than 25% and to form, by 2020, a complete system of high tech service industry of China.

## ***2.2. “Segmentation” in production of high tech products - new and increasingly clear feature***

Up to now, the trends of international scale share of works in the sector of high tech industries have shifted from the mode of “share between industries” to the one of “share within industries” and “share in products”. The international share of works leads to a multi-level type of share for a single product. The process of international share of works which has multinational companies as dominating forces gets fast pushed up. The case of Boeing is taken as example where the number of enterprises in the world collectively involved in manufacture of Boeing 787 aircraft exceeds the figure of 1,500 with the out-sourcing conducted for major part of core technological products. Even aircraft engines are assembled from parts made through large out-sourcing procedures including shells, blades, main shafts and transmission components.

In context of globalization, the attention for enhancement of capacities at a segment in the chain of values plays the same important role as the one for extension of other segments in the chain of values. Actually, in the high tech sector, the technological cooperation can bring considerable benefits for certain enterprises, nations and areas if they hold technological advantages in the model of multi-directional competition and networking. CMOS chips are taken as example. Here, by 2012, 76.5% of the world's total volume of CMOS chips was designed by the USA, 65% of wafer were manufactured by Taiwan, 78% of computer chips were manufactured by the USA, 54% of industrial chips were manufactured by Japan but the package of 75% of the world's total volume of CMOS was completed in South-East Asia. The USA, Japan, Taiwan and South-East Asia countries become core elements of the industrial chain of CMOS chips. In this chain, every country holds a niche market of their advantages in the competitive industrial chains.

### ***2.3. Integration of high techs as sign of diversification where the competition in industrial chain is substituted by the competition in chains of values***

Future trends of S&T and industrial revolution is not based only on a few individual sectors of industries but require a high level of in-depth mixing and integrating of numerous disciplines and sectors of technologies. Integrated technologies will define the orientation of the global markets in close future. By 2012, the world's major economies enhanced the scale of connecting high techs and research activities in inter-discipline sectors. For example, the US National Science Foundation (NSF) provided about US\$1 billion for the program "S&T of Moore Law", also the same amount for the program "Sustainability for Science-Technology-Education" and, at the same time, increased investments for the "National Program of Nano-Technologies". EU Commission announced "EU Key Strategies for Enabling Technologies" to push up the short cut of industrialization of enabling technologies in sectors of micro-nano electronics, nano technologies, electronic optics, advanced materials, industrial biotechnologies and advanced manufacturing technologies for intensive economic growth. Russia is focused on development of pharmaceutical industries, composite materials, non-metal materials, air industries, information technologies and nano technologies while maintaining traditionally advantageous positions in sectors of nuclear and aerospace technologies for implementation of large-scaled projects of scientific research. Another example is the Korea case where the Government will

make KRW513 billion investments for implementation of “2020 Year Nano-Integration Project”.

In actual stage, bio-technologies, information technologies, new materials technologies, new energy technologies, aerospace technologies, global marine technologies and etc. have gained important development on basis of promotion of integration of high techs in inter-sectorial areas. The trends to inter-link, to absorb and to re-structure the high tech industries on basis of “integration” orientation are implemented intensively. The “integration” is not only reflected in the combination of inter-discipline technologies but also in other aspects such as integrated involvement between different business actors, integration of hardware and software, integration of contents and products. The process of integration of high techs also leads to creation of new technologies, new products, new services, new market models, new business forms, formation of new chains of values different from the chain of traditional industries.

The competition of chains of industries is being substituted by the competition of chains of values as actually seen through the following 3 aspects:

- (1) Informatization has pushed up the integration of manufacture of individual products in direction of the entire chain of industries, extended the chains of industrial values, established the system of distribution of new values from “products of manufacture” to “values of manufacture” and then brought in innovations and development for technologies and business;
- (2) Integration of hardware and software has pushed up the integration of sectors of manufacturing industries and distribution. Machine operators get involved in the field of manufacture and manufacturing units get involved in the field of distribution;
- (3) Integration of high tech products and high tech services produces new models of markets and new trade forms. At the same time, the development of information technology, high quality manufacturing technologies and market diversity orientation has pushed up the diversification of specifications of equipment as output products.

### **3. Fast developing new technologies and new industries are creating new waves of industrial revolution**

Actually, information technologies, life sciences, bio-technologies, nano technologies, new energy technologies, space S&T, marine S&T experience fast development and compete among themselves to occupy the break-

through positions. Also, important S&T break-through moves in the above noted fields may become driving forces and lead to a new industrial revolution. For example, the changes in industrial sectors made on basis of technological break-through steps in technologies for exploitation of shale oil-gas, 3D printing technologies, US mobile Internet network and etc. have gained global attentions and lead to basic changes of global industries.

### ***3.1. US new technologies for exploitation of shale oil and gas lead to restructuring of the world's energy markets***

Actually, the world's volume of shale resources of oil and gas is estimated about 456,000 billion m<sup>3</sup> making about 50% of non-conventional gas resources of the world and being equal to conventional natural gas resources. These resources are distributed mainly in some regions and countries such as China, North America, Latin America, Middle East, North Africa and SNG. During recent years, the USA increases the exploitation volume of shale oil and gas providing 37% of supply sources of natural gas of the USA. By 2015, the USA overpasses Russia to become the world's No. 1 of natural gas producer. The USA can make huge volume exploitation of shale oil and gas because it masters the whole series of key technologies in this field such as horizontal drilling, hydraulic fracturing, logging while drilling (LWD), geosteering drilling, micro-seismic tests and technologies of system integration based on analysis of gas containing structures, data collection and assessment of geo strata, well drilling, disintegration, completion of wells and production operation.

Technologies of extraction of natural oil and gas from shale strata cause clearly impacts to the global models of energy supply. The successful development of the sector of shale oil and gas in the USA causes far going impacts to the world market of energy. It is seen clearly through the following facts:

- (1) The USA has formed a new industrial sector in exploitation and processing of shale oil and gas and then established a series of world leading professional service companies such as Halliburton, Schlumberger, Baker Hughes and etc;
- (2) The USA is successful to combine break-through technologies for commercialization of shale oil and gas and, at the same time, to set up plans to export these technologies. By this way, the USA can control and dominate the resources of shale oil and gas of other countries;
- (3) The successful development of shale oil and gas has changed the US energy model and caused major impacts to international energy supply activities and global political status. Recently, Russia and OPEC



announce to have to change energy strategies to cope with the trends of reduced prices due to the US considerable exploitation volume of shale oil and gas;

- (4) The US successes in this field encourage the moves of exploitation of resources of shale oil and gas in other countries including Canada, Germany, Poland, Australia, India and etc.

### ***3.2. 3D printing technologies lead to a revolution in manufacturing industries***

3D printing technologies also called as additive manufacturing are new technologies to manufacture 3D objects from digital models. These technologies had appeared earliest in the mid-90s of the 20<sup>th</sup> century. The development and break-through moves of 3D printing technologies lead consecutively to appearance of 3D products. Public mass media such as New York Times and The Economist evaluate that they are core technologies which may lead to a revolution of manufacturing industries. By 2012, the US National Additive Manufacturing Innovation Institute (NAMII) had made US\$70 million valued investment for research and development of these printing technologies. Also, EU arranges special funds to support research and development of 3D printing technologies at University of Nottingham, University of Sheffield, University of Exeter where 3D printing centers were established. China also sets up an Union of 3D printing technology industries.

3D printing technologies bring a revolutionary progress for manufacturing industries and turn upside-down many sectors such as industrial designing, new materials and lean manufacturing. Namely:

- (1) 3D printing technologies turn upside-down traditional manufacturing technologies. 3D printing technologies produce objects of any shape without needs of mechanical manufacturing or molding processes. Plants will say “goodbye” to traditional manufacturing tools and machines. Instead of that, there will be softwares which are more flexible and sensible to conduct manufacturing processes;
- (2) 3D printing technologies can be called green technologies because they are capable of saving energy and materials and to reduce waste. According to the data made publicly by the US Ministry of Energy, 3D printing based manufacture can make 50% saving of energy;
- (3) 3D printing technologies create unlimited capacities for industrial designing. Here designers can get free from constraints of traditional technological processes. Abbe Leiqintaer, CEO of the US 3D System

Company, states: “Only you cannot think out of that. Impossible that it cannot be printed out”;

- (4) 3D printing technologies let make the more flexible choice of manufacturing sites. 3D printing machines can be installed at any location. They may make single products specifically designated for individual users and, at the same time, make save transport and warehouse keeping costs.

### ***3.3. Development of mobile Internet network leads to deep changes in chains of traditional industries***

Mobile Internet networks are a combination of two networks of mobile information and Internet. Since 2012, the number of mobile Internet network users has experienced an explosive growth. According to statistic data, the 2011 year record of mobile Internet networks was 1,100 million subscribers, and the figure came up to 1,500 million subscribers within 9 months of 2012. The figure of China by 2011 was 429 million subscribers and it came up to 750 million subscribers by October 2012.

Together with the fast development of core technologies of mobile Internet networks, the wireless broad band technologies, mobile terminal technologies and fast increasing number of mobile Internet network users lead to radical changes in chains of industries. Mobile Internet networks make change competition structures of source technologies. In chains of traditional industries, the competition between segments and enterprises is very tough which may lead to reduce trends of benefits of enterprises. Mobile Internet networks are convergence points of integration of numerous sectors such as telecommunication, Internet networks, mass media, attractions, wireless broad band information technologies, mobile information and Internet network are all applied in mobile Internet networks. This also pushes up the integration and trans-border competition between various industries which lead to the vague roles of enterprises. Mobile Internet networks bring new models of business and trade. By other words, mobile Internet networks are changing the life and attraction activities of all people, even the mode of consumption, and, at the same time, make change the models of trading and manufacturing of products as well as the way of providing of services by enterprises.

## **4. Conclusion**

Trends to increase investments for S&T development, especially high techs, are observed continuously in the world, even during periods of financial crisis and crisis of public debts of some industrial developed countries. The

process of innovations in the global scale is being implemented intensively where S&T super powers and multinational companies keep leading roles. Break-through achievements in sectors of state-of-the-art technologies have created new industries and new models of development, and created new specific features in international share of works and global economic structures. The above analyzed developments show the appearance of new waves of industrial revolution, even a new industrial revolution. Economic cooperation and competition in the world scale are still characterized by dominating advantages of those nations and economic agglomerations who hold key advanced technologies.

Being a developing country and passing the stage of international integration, Vietnam needs to focus efforts on in-depth and multi-facial studies of trends of S&T development in the world in order to adapt to fast changing situations, to choose priority directions, scopes and right partners for S&T cooperation which let over-pass challenges, maximize use of offered opportunities and enhance the S&T position in development process of the country./.

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