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Introductory viewpoint

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Why Asia is heavily investing in research and development?

Every year around US$ 1 trillion is spent on research and development (R&D) in computing, telecoms and electronics; the United States accounts for over one third. But while corporate R&D in America and Europe grew by 1%-2% between 2001 and 2006, in China it soared 23%. China is now close to overtaking Japan in total research spending, from about nothing ten years ago. The biggest and most technologically advanced firms are American and European, but their predominance in research, innovation and production is being challenged by Asian companies. For instance, although the firm that sells the Apple iPhone is American, the components are almost entirely Asian: the screen is mostly from Japan, the flash memory from South Korea and it was assembled in China. Apple's contribution is design and software - and importantly, integrating the innovation of others (*The Economist*, 3 January 2009, p. 47).

A survey made by the Organization for Economic Cooperation and Development (OECD) has shown that the United States remain by far the superpower in R&D with a total spending of US$ 280 billion (198 billion euros) in 2005, compared with US$ 199 billion for the European Union, US$113 billion for Japan, and US$ 101 billion for China (Perucca, 2009).

China has more than doubled its R&D spending between 2000 and 2005, so that its share in world spending rose from 6.2% to 11.8 % (total global spending in R&D in 2005 amounted to 851,983 million euros), according to the Report of the French Observatory of Science and Technology (OST) published by the end of 2008. While public spending has soared 20% between 2000 and 2005 and increased by 4% in the European Union, decreased in Japan (-19%) and China (-20%). In contrast, the private sector has been spending more in R&D in China and Japan (Perucca, 2009).

A list of the world's 250 biggest technology firms shows that Taiwanese companies spend more on R&D than British and Canadian ones. However, Taiwan generally does lower-end work like making semi-conductors. More sophisticated tasks, such as designing the chip's circuitry, are still mostly done in the West. The most impressive growth has been in the Republic of Korea. In 2007, Samsung spent more on R&D than IBM. The company has been rated to second place in the number of patents granted by the US Patent and Trademark Office (USPTO), just behind IBM; a decade earlier it was not even among the top ten. Firms in the Republic of Korea (ROK) spend more on R&D as a percentage of sales (6.5%) than European and Japanese firms (about 5%), and are catching up with US ones (some 8 %) (*The Economist,* 3 January 2009, p.47).

The amount that US firms spent on research in computer services as much as trebled over the past decade. Japanese and ROK firms, meanwhile, spent hardly anything developing services, and preferred to focus on more tangible, if less lucrative, hardware. In computers and office equipment such as copiers, America and Japan actually traded places: America's R&D expenditure on such items fell by one third between 1996 and 2005, while Japan's more than doubled to US$ 13 billion, the amount America used to spend. India, meanwhile, has concentrated on services *(The Economist,* 3 January 2009, p.47).

In 1999 around 90% of Asia's international internet traffic passed through America; in 2008, the share dropped to 54%, according to TeleGeography, a telecommunication research firm. It is another example of how the communication technology industry, once dominated by America, is becoming global in nature (*The Economist*, 3 January 2009 p.47).

Another significant indicator mentioned in the OST's report is the world distribution of students and research staff. Of the 140 million students in the world by the mid-2000s, 40.3% were in Asia, 25.8% in Europe, 15.3% in North America, 9% in Central and South America and 5.6% in Africa. Although a small proportion of its population has access to higher education, China is the country with the highest number of students: 23.4 million, compared with 17.3 million in the United States. Of the 6 million researchers in the world, 35.2% were in Asia, compared with 32.8% in Europe and 25.4% in North America. The United States had 1.4 million researchers, compared with 1.3 million in the European Union and 1.1 million in China. Taiwan now has more high-technology researchers than the United Kingdom, and the Republic of Korea has more of them than the United Kingdom and Germany (Perucca, 2009*; The Economist*, 3 January 2009, p.47).
However, it is in Japan that the number of researchers per 1,000 active people is the highest: 10.6, compared with 9.21 in the United States and 5.70 in the European Union, far ahead of China which has only 1.43 researchers per 1,000 active persons (Perucca, 2009).

The number of scientific publications is also a good indicator of the progress made in R&D. The share of Asia in the global number of publications increased from 18.3% to 22.4% between 2001 and 2006. China has jumped to the third rank in the world (a 96% growth during the period 2001-2006) with 7% of world publications (including all fields of research). However, not only the European Union remains the undisputed leader (33.3% of the world total), ahead of the United States (26.2 %), but the "impact" of these publications (i.e. the number of citations following a publication) is much higher for the US and Europeans than for the Asians (Perruca, 2009).

Regarding the requests for European patents, the share of Asian countries has soared 41%, while requests from Europe and North America decreased by 11% during the period of 2001-2006. Among Asian countries, ROK's requests rose by 205%, while those of China moved up 124%. The OST's report underlined the progress made by China in the requests for patents in electronics and electricity, by India in chemistry, materials and pharmacy/biotechnologies, and the Republic of Korea in instrumentation. However, on world level, the European Union with 37.3% of the total number of requests for patents, the United States with 28.9% and Japan (17.8%) predominate. These three groups of countries also play a major role in the requests for patents in the United States: 51.3% for the US, 21.3% for Japan and 14.7% for the European Union. But their shares, in both the European Union and the United States, tend to decrease (except in the case of Japan) in favour of China (+261%) and of the South-East Asian countries (ASEAN, +84%) (Perucca, 2009).

All these numbers highlight, on the one hand, the increasing investments in R&D made by Asian countries, which become strong competitors of the West and on the other, the rivalry between "new Asia" and "old Asia", as stated by Sacha Wunsch-Vincent of the OECD, one of the survey's authors. Japan and Taiwan are being challenged by China, India and ROK.

There are two reasons for this trend in the case of China:
- the saturation of economy leads to the gradual need to climb up the added-value chain, in order to produce more sophisticated and high-technology products; this is also true for East-Asian countries;
- the effects of globalization.

According to Jean-Joseph Boillot, a French economist associated with the French Centre for Prospective Studies and International Informations (CEPII), both reasons are valid for China. For instance, the closing up of factories in 2008-2009 are not only the result of the financial and economic crisis, but it also meant the will to invest in more sophisticated factories, such as that of Hua Wei, often quoted as an example, and is the world's second leader in telecommunication, ahead of Alcatel. In the motor-car industry, Chinese manufacturers that have joint-ventured with the world's biggest companies in this sector, have created their own R&D centres. China indeed knows that it cannot rely anymore on abundant and cheap labour, and on low-cost products (Perucca, 2009).

In addition, China understood that it had to produce not only high-technology products but also environmentally-friendly ones. There are now in China cities where all motorcycles use electrical power, e.g. in Chengdu, capital of Sichuan. China could become a leader in solar energy production and use, thereby trying to move to an energy-consumption model less dependent on fossil energy (Perucca, 2009).

China is requesting all companies that outsource their production on its territory to also transfer technology, because innovation is still lagging behind. The reason may be that it is difficult for innovation to thrive in a constrained political and social system.

Globalization is therefore a major trend that will favour openness and subsequently more innovation.

This is where India differs from China and the East Asian countries. Thanks to its openness to the rest of the world, in particular thanks to the use of English, India has chosen to be part of the global R&D system. In three years, some 450 research centres with several hundred persons each have been created. Whole international R&D laboratories are set up in India (e.g. Alstom), not only to carry out basic research, but also development (Perucca, 2009).

Why Gulf States finance alternative sources of energy and R&D in this area?

With one of the highest per capita footprints in the world, Abu Dhabi, United Arab Emirates (UAE) is an oil-rich country, where gasoline sells for US cents 65 a gallon in 2009, when there is little public transportation and no recycling. Air-conditioned department stores are lit 24 hours a day, seven days a week. Yet its leaders understand that oil is a finite resource and vulnerable to competition from alternative sources of energy. Consequently, the UAE, as well as Qatar and Saudi Arabia, are investing billions of US dollars, derived from their oil exports, into "clean" energy, behind research projects at universities in Japan, the United States and the United Kingdom (Rosenthal, 2009).

Khaled Awad, a director of Masdar, a research park and a futuristic zero-carbon town (*Masdar City*), partnering with the Massachusetts Institute of Technology, stated: "Abu Dhabi is an oil-exporting country, and we want to become an energy-exporting country, and to do that we need to excel at the newer forms of energy". That means long-term investment in R&D, at home and in affiliated research centres. In addition, Abu Dhabi organized the second World Future Energy Summit from 19 to 21 January 2009, that has been attended by Gulf States' political leaders, top energy officials from the European Union and executives representing hundreds of companies large and small, from British Petroleum (BP) and Crédit Suisse to start-ups companies from Europe and the United States. This summit is poised to become a Davos for renewable sources of energy (Rosenthal, 2009).

The world is now consuming 80 million barrels of oil a day and that could rise to 150 million if population and consumption trends continue. That would mean adding six Saudi Arabia's worth of oil output just to keep up with current consumption, at a time when CO_2 emissions and greenhouse-effect gases must be cut significantly in order to mitigate disastrous global warming (Rosenthal, 2009).

The reasons for this new investment are: to maintain the Gulf's dominant position as a global energy supplier, gaining patents from the new technologies and "green" manufacturing; and to ensure a high-end lifestyle of their populations in the coming years and decades. Current growth based on very high fossil energy consumption is not sustainable and Abu Dhabi must develop new models, not only for itself, but also for the rest of the world.

In January 2009, Abu Dhabi's crown prince announced the Emirates would invest US$ 15 billion in renewable energy, i.e. the same amount the US president has proposed investing in the whole United States, in order to "catalyze private sector efforts to build a clean energy future". Masdar City that will generate no CO2 and greenhouse-effect gases, is part of the crown prince's ambitions. Designed by Norman Foster, the British eco-architect, it will cooperate with MIT and offer research parks including laboratories affiliated with Imperial College London and the Tokyo Institute of Research and Technology (Rosenthal, 2009).

Nancy Tuor, vice-chairman of CH2M Hill, the Canadian construction firm that is building Masdar City, stated that the sheer size of the investment has had a "forcing effect" pushing polluting industries to experiment with environment-friendly solutions. For instance, initial plans of the City complex excluded both aluminium and conventional concrete, since the manufacture of those materials generate high amounts of CO2 emissions. Aluminium manufacturers had to come back with a product that reduced emissions by 90% compared with regular aluminium. Likewise, all concrete in the project is made with alternatives to cement. The machinery ordered for the construction runs on diesel and with the highest European fuel efficiency standards. The city will have no cars, and people will use driverless electric vehicles that move on a subterranean level. The air conditioning will be solar energy powered. Investors hope the technologies and patents that will come out of the R&D in the Gulf States will give the country an advanced manufacturing sector focused on renewable sources of energy and materials (Rosenthal, 2009).

In Saudi Arabia, the new state-owned King Abdullah University of Science and Technology (KAUST) allocated a US$ 25 million grant to Michael McGehee, director of the largest solar cell research group in the world at Stanford University, to start a research centre on how to make solar power cost competitive with coal. KAUST also allocated US$ 8 million to a researcher at the University of California, Berkeley, who is developing environmentally-friendly concrete. KAUST has other agreements with Caltech, Cambridge, Cornell, Imperial College, Oxford, Sapienza (Rome) and Utrecht universities (Rosenthal, 2009).

The huge investments made may enable researchers to generate many emerging technologies, like those dealing with carbon capture, microsolar and low-carbon aluminium, and make them more effective. Michael McGehee stated that "it has greatly accelerated the development process", in particular with respect to developing cheaper solar cells. He could not obtain the needed subsidies from the US government for the same purpose. Saudi money paid for 16 new researchers, and the US scientist expected the new energy cells to dominate the market by 2015 (Rosenthal, 2009).

In December 2008, as Gordon Brown, the United Kingdom's prime minister, visited Qatar, the government signed an agreement to invest £150 million, or US$ 270 million, in a British low-carbon technology fund (Rosenthal, 2009).

To sum up, Gulf States that have previously showed little interest in renewable sources of energy, like solar or wind energy, are now investing huge amounts of money in R&D concerning these alternative energies, at home and through grants to research groups in the United States and Europe. They do so because they understood that relying on a fossil energy based economy and lifestyle is not sustainable; because they could keep a dominant position in the new energy market and pocket royalties from the patented innovations. These are development, social and political challenges.

Biotechnology, innovation and public health: Cuba's experience

Cuba, a small country of 12 million people, has shown that after two decades of investments and efforts on training and retraining highly qualified researchers it could create an efficient medical and pharmaceutical biotechnology industry. The latter is not only useful to national public health, but also is a source of much needed income.

Why so? Before the Cuban revolution, i.e. before the 1950s, medical training and research was the privilege of few teams and some distinguished scientists such as Carlos Finlay, who discovered the virus of yellow fever and whose name is now that of an important vaccine-producing institute. The Marxist revolution believed in science and technology as a driving force for social change and progress. *Public health for all* was an imperative goal which was progressively achieved through the training of numerous physicians and with an effective network linking patients in their living space and with their medical doctors. Medical biotechnology was chosen in the mid 1980s as an area of excellence where Cuba could innovate and sell diagnostics, vaccines and drugs, embark into joint ventures with other countries, developed and developing ones. This was indeed a success story, politically supported at the highest level of the state, well planned, focused and socially oriented. It has become a subject of self-pride.

Thus, in the last 20-25 years, in the area of immunology, Cuba is the home about 600 immunologists, 10 research institutions in the field, a national network of 137 immunodiagnostic laboratories, as well as several centres for the production of vaccines, antibodies, biopharmaceuticals and diagnostic tests. Agustín Lage, director of the Centre of Molecular Immunology (CIM), stated: « the most remarkable aspect of Cuban immunology (biotechnology) was its strong connection with public health".

Cuba, indeed, enjoys a very vast vaccination programme which includes the protection of newborns against 13 diseases; epidemiological vigilance using immunoassays of over 20 diseases. Hospitals use drugs such as recombinant interferons**,** monoclonal antibodies, cytokines and other biopharmaceuticals, produced locally.

It is true that a successful public health policy cannot be attributed only to effective medical action and use of modern technologies, but it is also true that the efforts made by Cuba over the last 25 years in medical biotechnology have contributed to decreasing infant mortality down to 6 per 1,000 births and to increasing life expectancy to 77 years. Several communicable diseases have disappeared (poliomyelitis, diphtheria, small pox) and others are under strict control (hepatitis B, meningoencephalitis and meningitis B).

Agustín Lage has underlined that the link between research on immunology and public health is biotechnology. This is not surprising because 70% to 75% of biotechnology products worldwide are related to immunology. Many biopharmaceuticals and vaccines are being produced by the new biotechnology start-ups and commercialized by the big pharmaceutical companies.

In Cuba, by the mid-1980s, a research pole and complex started to be built west of Havana and lumping together more than 40 organizations and 12,000 employees, including 7,000 scientists and engineers. Nowadays, the products of these R&D institutions are exported to 40 countries: 11 vaccines, more than 40 biopharmaceuticals (recombinant proteins and monoclonal antibodies); immunodiagnostics. There are about 91 new products in the development process and more than 60 clinical trials are being carried out in 65 hospitals. Furthermore Cuba's biotechnology centres have filed about 900 patents outside the country.

All these figures show that the following challenges had to be met: provide a good research basis, and setting up effective connections between research, production, education and training, and public health. Supported by a constant political will and a steady investment policy over more than two decades, multidisciplinary research teams working in different sectors and R&D areas, have been able to develop new technologies and products, i.e. to generate innovation. In Cuba, this innovation has its origin in the national commitments for public health.

In other developing countries that also produce vaccines, diagnostics and drugs, like China and India, innovation has been generally promoted by the ministries of industry or of science and technology. The example of Cuba and, to some extend, of Brazil, may lead some countries like Argentina, which has a strong biomedical research, to closely associate bioindustry with the needs of public health, i.e. with social needs. In February 2009, during her visit to Cuba, Argentina's president signed a cooperation agreement with Cuba in medical and pharmaceutical biotechnology.

The challenge for higher education: the case of India and China

At the heart of China's ideology, confucianism makes a strong advocacy for education, work, obedience, social morality, and, like in Singapore, promotes a modern and dynamic economy, led by the state. Thanks to the top priority given to education, this ideology coexists harmoniously with a knowledge-based economy. In China, as elsewhere, there is a transition from a system that conceives education as prescribing a social behaviour, valid in a national context, to a system where education means training and acquiring knowledge in a globalized context (Verellen, 2008).

In China, the top priority is to integrate foreign knowledge and know-how and to adapt them to its economic needs. This process is characterized by a tension between openness and internationalization, on the one hand, and retention and censorship needed to maintain control, on the other. Nowadays, the reference for Chinese university people is the West, followed by Japan. Chinese universities, as well as those of the Republic of Korea, are struggling to be among the first levels of the ranking established among world universities and published since 2003 by Jiao-Tong university of Shanghai. Chinese universities appear in that ranking at the 200th level (Verellen, 2008).

In China, access to higher education has quadrupled in eight years and, in 2006, students admitted in universities represented 22% of an age class, with nevertheless important regional disparities. Graduated Chinese students were 5.6 million in 2008, i.e. more than Denmark's population, including 600,000 engineers. In addition, the training of an increasing number of Asian graduate students should be underlined: in 2005, 24% of PhDs and Master degrees in sciences and engineering delivered in the United States have been awarded to Asian students (Verellen, 2008).

The impulsion of higher-education reform in China is not an isolated process in Asia. Japan, ROK and Taiwan have carried out (and are carrying out) similar reforms of their higher-education system and research. Some countries, like Japan, prefer to concentrate the state's subsidies on national centres of excellence, but in general higher-education institutions must find complementary resources. They set up evaluation systems so as to measure their performance and they adopt more efficient management systems. All these reforms aim to reach levels of excellence in a knowledge-based society (Verellen, 2008).

To sum up, higher-education systems of China, India and other Asian countries are responding to the challenges of globalization and innovation needed to compete on the world market. In the case of China, this movement is not in contradiction with the confucianist approach to a dynamic and modern economy, as well as to the priority given to education and work. The huge investments made by these countries in education as well as the openness to the world is a major stake for Asia, but it is also a reminder to wake up for those who are lagging behind in the world competition.

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