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Notes

Human Capital, Science, Technology and Development

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Introduction

There was a renaissance of the economics of education and indeed of human resources in general in the late 1950s and early 1960s according to Louis Emmerij, the president of the Organization of Economic Cooperation and Development (OECD). He noted that Irvin Fisher in his classic work on *Capital and Income*, had drawn an explicit link between physical and human capital and the foundations of a generalized capital accumulation approach to development. However long before economists started taking interest in human resources as factor in economic development J. D. Bernal, a British scientist, impressed by the rapid transformation of Russian society through planned development of human resources, science and technology and their use in economic development had advocated the planned use of science and technology for development in his book, *Social Function of Science*. This book published in 1939 greatly influenced political leaders like Nehru struggling against colonial rule. He used its prescriptions soon after gaining independence, while laying down guidelines for planning for development in independent India. After the Second World War (1939-45) economists also noted the important role of human capital in the extremely rapid recovery of Germany despite her destroyed capital stock. The importance of scientific research and development (R & D) had already been proved during the war when atomic bomb, radar and many other inventions had been developed. Besides the use in war, the importance of R & D in innovation and production of new goods and services well established among the industrial and business circles also gained acceptance among governments in developed countries. UNESCO has also promoted the development of education, science and R & D among the developing countries.

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According to World Bank *World Development Report 2007,* high income countries located in Western Europe, North America, East Asia and Oceania and grouped in the Organization of Economic Cooperation and Development (OECD), though having less than 16 % of the world population generates nearly 79% of the world gross domestic product. They also spend between 2~3 percent of their gross domestic product (GDP) on R & D. On the other extreme are the low and middle income countries having a population of nearly five and a half billion, more than five times that of the high income countries produce just 21 % of the world GDP. They also spend insignificant percentage of their GDP on R & D. Thirty years ago the share of the OECD countries in world GDP and R & D expenditure was even larger. However that was not always the case.

Historical roots of underdevelopment

It is estimated that living standards in eighteenth century in most of Asia were at the level that were prevalent in Europe and America. According to Paul Bairoch China and South Asia produced 57.3 per cent of the world production in the 1750s. The share of Europe in that decade was slightly over 23 per cent. The situation started changing in the next decade. The Industrial Revolution and the rapid adoption of new technology based on new source of energy (coal), steam engine and steel, Britain soon outstripped all others in economic development. She raised her share of the world manufacturing output from 1.9 percent in 1750 to 22.9 per cent in 1880. During the same period South Asia’s share declined from a high of 24.5 per cent under indigenous control to 2.8 per cent under British colonial occupation.

Table 1: Relative Share of World Manufacturing Output 1750-1900

	1750	**1800**	**1830**	**1860**	**1880**	**1900**
Europe	23.2	28.1	34.2	53.2	61.3	62.0
UK	1.9	4.3	9.5	19.9	22.9	18.5
France	4.0	4.2	5.2	7.9	7.8	6.8
Germany	2.9	3.5	3.5	4.9	8.5	13.2
USA	0.1	0.8	2.4	7.2	14.7	23.6
Third World	**73.0**	**67.7**	**60.5**	**36.6**	**20.9**	**11.0**
China	32.8	33.3	29.8	19.7	12.5	6.2
South Asia	24.5	19.7	17.6	8.6	2.8	**1.7**

The gap between the living standards of ordinary people in Western Europe, North America and those in Asia, Africa and South America started to widen, as most of the world was brought under the colonial occupation of one or the other of the newly industrializing capitalist countries, Britain, France, Germany, Belgium, Italy and USA. In the year 1800, Europeans occupied or controlled 35 per cent of the land surface of the world; by 1818 this figure had risen to 67 per cent and by 1914 to over 81 per cent.

Technology, science and colonialism

The basis of the Britain supremacy throughout the 19th century was her mastery of new industrial technology based on coal, steam engine and steel production. The new technology of iron production gave Britain a head start over other European challengers like France and Germany. From 1860s onward the newly unified German nation state under Bismarck used her superior educational institutions and organized research to overcome backwardness in industrial manufactures. Germany was the first country to establish a new type of institution, the so-called Research University, to generate new knowledge as well as to train the manpower needed for the newly emerging industrial society. German model was later emulated in the fast industrializing USA in the late 19th century.

Germany was the first to use trained chemists in a big way and achieve a lead in industrial chemistry. By the end of 19th century six largest German chemical works employed more than 650 chemists and engineers, while the entire British coal tar industry had no more than thirty or forty. By 1900 Germany had overtaken Britain in steel production. In 1913, before the war started German steel production was double that of Britain. By then the total industrial potential of Germany was 137.3 compared to 127.2 for Britain. Relative share of Germany in world manufactures had also surpassed that of Britain.

Britain had achieved her economic and political position on the basis of the industrial revolution that was ushered by entrepreneurs trying to overcome shortages of traditional sources of power and manpower. They were technologists, rather than scientists; men like Savery, Newcomen, Watt, and Wilkonson who developed the steam engine as the new source of power for the industrial revolution as was Darby who developed the first successful coke smelt iron and Hargreaves, Arkwright and Crompton who developed the machinery for the mechanization of textile industry. In Industrial revolution science was incidental to production. However, the rise of the next generation of industrial countries, Germany and USA was rooted in the exploitation of the physical and chemical sciences whose basis had been laid down by the 1860s. The new automotive, electrical and chemical industries were based on physics and chemistry. It was Charles A. Parson, a professor of physics, who invented the high-speed steam turbine that revolutionized sea transport. Science from being incidental to production became the basis for it.

USA and German industrialists were the first to realize the importance of scientific research. In USA, Carnegie put a German chemist to work at the start of the 1870s and was able to standardize the manufacture of pig iron. General Electric enlisted the German physicist C. P. Steinmetz, chiefly to design alternating current equipment. Thomas Edison set up the first research organization for the specific purpose of systematic invention, in 1876. The first government laboratories were established by the Department of Agriculture under an act of the US Congress, in 1886. Arthur D. Little began his independent research laboratory in 1886. These were the forerunners of the corporate research organizations: Eastman Kodak (1893), B. F. Goodrich (1895), and most important General Electric (1900). General Motors (GM) did a great deal of its research through Charles F. Kettering's Dayton Engineering Laboratories Company (DELCO), organized in 1909 and acquired by GM in 1919. At the same time the corporation also set up other laboratories, such as the one organized for it by Arthur D. Little Company in 1911 to do material testing and analysis. Bell Telephone set up its research laboratories in 1904. Westinghouse Research laboratories were started in 1917. By 1920 there were perhaps three hundred such corporate laboratories and by 1940, over 2200. By then, corporations with a tangible net worth of over $100 million averaged research staff of 170, and those with a net worth exceeding a billion dollar averaged research staff of 1,250. The Bell Telephone Laboratories employing over 5,000 was the largest research organization in the world. New monopolies based on the exploitation of physics and chemistry that were created by inventors and scientists have survived into the new millennium.

Judicious use of science and technology helped USA to raise her share from an almost insignificant share in global production in 1800 from 14.7 percent in1880 to 23.6 in 1900, to 32 in 1913 and to 43.3 per cent in 1929 compared to UK's share that declined continually from 22.9 in 1880, to 9.4 percent in 1928. The rise has been on the basis of new technologies of production (Taylor's assembly line continuous production) and new sources of power, oil, electricity, gas, new technologies of internal combustion engine, electrical appliances, telegraph, and chemical dyes. US had emerged as the new innovators of technologies.

Higher education and rise of industrial society in USA

At the threshold of the 20th century the United States had a small but vigorous graduate education enterprise rooted in a new kind of institution, the research university. The distinctive feature of the research university was the doctoral program. In 1900 most of the approximately 250 research doctorates conferred were from the dozen or so new research universities in the Northeast and Midwest. The next 100 years of doctoral education were marked by growth and diversification. By 1999 the number of research doctorates conferred annually had reached more than 41,000, with these representing nearly 400 institutions across the United States. Between 1900 and 1999 the U.S. graduate education system developed into an integral part of the social and economic structure of the country, contributing to the nations economic standing and also constituting a significant component of the U.S. economy. By the end of the 20th century, a total of 426 institutions had awarded more than 1.36 million doctorates.

USA has maintained this position through out the 20th century. In this its education system has played a most significant part. The system continues to produce the educated manpower needed for the industry, society and the R & D system.

Characteristics of industrial societies

Societies while making a transition to industrialism educate all their children, banish illiteracy, provide schooling to all their children and youth (up to 18 years) and generally promote education and research. Modern knowledge system, with its public school, colleges, universities and research institutions is the product of such societies. They generate new knowledge at an exponential rate, doubling every 15 years. This knowledge is generated by scientists whose number also grows exponentially.

For example the number of PhDs per million of population reaches hundred and more in these countries. The number of scientists and engineers per thousand of population reaches 100 or more. The expenditure on scientific research and development (R & D) reaches 1-3 per cent or more of gross national product. The productivity and efficiency of the worker increases continuously. Even agriculture gets totally mechanized and science based.

Developed state of science gets reflected in production of large number of books, journals and research papers. In 1993, USA, UK, China, Korea and India produced over fifty thousand, 14003, 18559, 6913 and 1396 new titles respectively dealing with science and technology related subjects.

The Second World War, atomic bomb, decolonization and the rise of state support of R & D

Colonialism was made to retreat after 1945 and was finally routed in 1975 with the success of liberation movements in Mozambique, Angola, Guinea Bissau and Viet Nam. The number of independent countries rose to over 170. However centuries of colonial rule has left its scars in the extremely underdeveloped economies of former colonies. These countries have been called sometimes underdeveloped then developing and most recently low income. Despite changing labels the income gap between the richest 20 per cent and the poorest 20 per cent in the world rose from 30:1 in 1960, to 60:1 in 1990, and to 74:1 in 1999, and is projected to reach 100:1 in 2015.

However, while most of the countries that were formerly under colonial control have not been able to recover from the trauma suffered during the colonial rule a few countries especially in East and South East Asia have been able to industrialize and prosper. This has started to appear in the statistics tables annually prepared by World Bank and other international bodies like UN. Although most of the world population lives in developing (poor) countries, most of the qualified manpower that creates knowledge, science, technology and world GDP lives in developed countries. Figure below illustrate this graphically. The population of 15 years old and older with tertiary education that various countries produce is shown in the figure.

In 1980 of the 73 million such people, United States had 31.1%, Japan had 9.9% and UK, France, Germany together had 7.5 %. Together these five countries had nearly half (48.5%). In twenty years because of the rapid progress made by China, India in their higher education sector, the share of developed five was reduced to 40% of a much larger number (194 million). China and India now account for 10.5 and 7.7 percent of the total. This is reflected in the rising share of China and India in the world GDP.

Education and human capital

Education plays a most crucial role in the development of the human capital so vital for the acquisition of knowledge, science & technology that is essential for a country development. Most countries have sought to develop a science and technology policy. Using these policies along with other policies in the sphere of education, industry, finance, investment, import/export etc., such countries have achieved accelerated development. Japan, Korea and China are representative examples. They have followed the examples of older industrial countries. That have while industrializing, educated all their children, banished illiteracy, provided schooling to all their children and youth (up to 18 years) and generally promoted education and research. They have also created a modern knowledge system, with its public school, colleges, universities and research institutions characteristic of industrial societies.

Industrial societies have historically generated new knowledge at an exponential rate, doubling every 15 years. This knowledge is generated by scientists whose number also grows exponentially. For example the number of PhDs per million of population reaches hundred and more in these countries. The number of scientists and engineers per thousand of population reaches 100 or more. The expenditure on scientific research and development (R & D) reaches 1-3 per cent or more of gross national product.

However in addition to possessing qualified manpower another requirement is active engagement with Research and Development (R & D) activities that lead to creation of new knowledge, science and technologies that help in the production of new goods and services.

During the last 200 years and especially since 1850s almost all the inventions that have revolutionized agriculture, industry, communication, travel, entertainment, health and general living have been made in Europe and North America. It is only since the second half of the 20th century that other countries like Japan have joined the league. Since the late 80s and Korea, Taiwan and lately China have become significant players. As they have invested heavily in education, achieving universal elementary education and providing secondary and tertiary education to large number of their citizens. They have also invested heavily in research and development (R & D.).

Relation between science and development

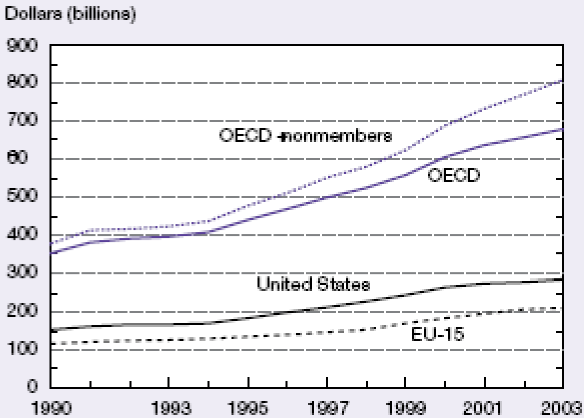
It is an empirical observation that the state of development of a country as represented by her gross domestic product (GDP), the sum total of all the goods (agricultural, mineral and industrial) and services (banking, commerce, insurance etc.,) is directly related to the amount of resources the country devotes to scientific research and development (R & D).

Take the case of the industrialized countries grouped in the Organization of the Economic Co-operation and Development (OECD). These include the European countries of the European Community (EC), North America, and Japan. In the year 1993 North America, EC and Japan together spent over 382,219.8 million dollars on scientific R & D.

They also employed a total of 2413372 R & D researchers in the same year. They also filed patents for over one and quarter million new scientific and technological ideas and products in the year 1990. They held among themselves 98.2 per cent of all European and 96.3 of all US patents in 1993.

The worldwide R&D expenditures rose from $382 billion in 1993 to $810 billion in 2003. The OECD countries' share dropped from an estimated 93% to 84% of the total over the period, based on the reported R&D expenditures of eight non-OECD members whose 1995–2003 average annual growth rate of.17.1% compared with. 5.6% annual growth for OECD members.

Figure O-1
Estimated worldwide R&D expenditures: 1990–2003



EU = European Union; OECD = Organisation for Economic Co-operation and Development

NOTE: Current dollars converted with purchasing power parities.

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

Science and Engineering Indicators 2006

Dominance of the US

As the 21st century begins, the USA continues to occupy a position of eminence as producer of new science and technology. In the year 2003, research and development (R&D) expenditure reached $291.663 billion. Of this the Federal government contributed $81.004 billion, while the industry contributed $193.420 billion. The universities, colleges and other non-profit institutions contributed another $17.24 billion. Of this amount universities and colleges spent $37.491 billion, while federal government institutions spent another $21.566 billion. R&D performing industries increased their net US sales from 4,925.124 billions in 1999 to 5,249.573 in 2000. In 1999, US economy employed a total of 10,479,800 science and engineering (S&E) graduates (57% Bachelor's degree, while 2.9 million had Master's degree and 722 thousands had a doctorate). Of the over ten million, 3,540,800 were employed in science and engineering professions, of these 484,100 had doctorates, 1,032,100 had Master's and the rest Bachelor's degree.

US is the biggest producer of five knowledge intensive services five high technology industries (aerospace, pharmaceuticals, office and computing equipment communications equipment and scientific instruments), which contributed a total of over $3,484 billion to its GDP in 1998.

New challengers

Other newly rising industrial countries (China, Korea, Taiwan, Singapore, Malaysia, Thailand) are increasing their expenditure on education, science, technology acquisition as well as on R & D. They are successfully challenging and cutting into the share of traditional high technology producers. Their educational institutions are turning out increasing number of scientists, engineers and technician for their fast growing industry. Their R & D activities are leading to an increase in their share of the patents registered in the world, an indication of the maturity of their scientific community.

International Herald Tribune of 4 December 2006 reported that China has become the world's second biggest R&D performer, according to data compiled by OECD; Chinese R&D spending would be over US$136 billion in 2006, more than ten times the figure of $12.4 billion in 1991.

China has cultivated science in a big way. In 1993 there were altogether 2,426,300 S&T personnel. Of these 1,484,300 were scientists and engineers. In the year 2002 the number increased to 3.22 million of which 2.2 million was scientists and engineers. The number of R&D scientists and engineers had reached 966,000, in 2006, an increase of 77 per cent in a decade. This puts China ahead of Japan's (677,000) and just behind United States' 1.3 million. The reports further notes that 'China plan to become a major innovation economy by 2020 is probably the most significant (among developing countries) as it will launch a series of reforms and strategic projects to make research and innovation the motor of its new economic development strategy.

The vitality of the S&T system in China has been due to a continuous influx of new talent. Chinese universities and other institutions of higher learning are the cradle of future scientists and engineers. In 1993 the total enrolment at under-graduate level in Chinese universities and colleges exceeded 2,536000 and that of post graduate students reached 107,000 (including 18000 for doctoral degrees). In the same year 571000 undergraduates and 28000 postgraduates completed their studies. Since 1990 the proportion of students majoring in science and technology has remained at 40% of the total undergraduate enrolments and 63.7% of the postgraduates and the proportion of doctoral students is even higher. By 2006, 16 million students (20% of the college age population) were enrolled in higher education. In 1999, the percentage enrolled was half at 10%. Every year the number of students enrolled increases by about 700,000 to 900,000.

According to a Chinese commentator, 'evidence shows that scientific research has provided knowledge, theories, methodologies, thoughts and talent that have contributed to economic and social development in China'.

One consequence of which is that industry in China has grown at the rate of 10 per cent from 1965-80 and at 12.4 percent from 1980-88 and at a hefty rate of 18.5 from 1990 to 1995. Its share has risen to 48 in 1993, while that of agriculture has decreased from 34 per cent in 1970 to just 19 percent in 1993. In 2003, China had surpassed Japan as a producer of high-technology. China's rise from a mere $23 billion in 1990 to $224 billion in 2003, remarkable both for its speed and consistency, moved its share of world high technology exports to 12%, beyond Japan's share. It is underscored by the growth of China's industrial research workforce, which expanded from 16% of the size of its US counterpart in 1991 to 42% in little more than a decade.

Pakistan's dependence on imported science and technology

Organizations entrusted with science, technology and R & D have not contributed significantly to the scientific and industrial development of the Pakistani nation. After over sixty years of independence, there is hardly any sector in Pakistan's industrial, agricultural, service, social and cultural life which is not dominated by products and services provided by imported science and technology. Even the most traditional sector of economy, agriculture, has also come to depend heavily on imported pesticides, fertilizers, hybrid high yielding varieties of seeds, Agricultural machinery (harvesters, tractors and other machinery). This massive input of science in agriculture has allowed steady increase in the yield of various crops. However, the productivity of our agriculture with some exception is still far below the world standards.

If we disregard the traditional herbal medicine, then our dependence on imported medicines, diagnostic and therapeutic instruments and chemicals is almost total. We have also come to depend almost totally for amusement and entertainment on imported scientific and technological marvels like DVDs, VCRs, tape recorders, players, televisions, films. The same is true for communication. We import satellite communication technologies, cellular telephones, as well as aero planes, cars, trucks and other self propelled machinery.

Our industry is mostly based on imported plants and raw materials. Even for our defense we have to depend on imported jet fighters, submarines, frigates, tanks, rockets, radar and sophisticated ammunition.

Our dependence on imported scientific know-how, equipment and services has increased manifold since 1948. We have to pay heavily for the use of imported technologies and patents.

Reasons for failure

The reasons for the failure of Pakistani scientific R & D to contribute to national economy are many. Successive Pakistani governments and Pakistani society in general have not clearly understood the role of education, science, technology and R & D in national development. They have therefore never made any serious effort to develop Pakistani science. They have never had a science policy till one was formally announced in 1984. However, there has never been any serious effort to implement that policy. Moreover, the material and human resources invested in science and scientific R & D have always been very insignificant. The only research organization that has been funded adequately is Pakistan Atomic Energy Commission and the Kahuta Research Laboratories. A serious attempt has been undertaken since the year 2000 to develop higher education sector and increase research and development efforts by massive infusion of resources. The effort has yet to bear fruit. It has been severely criticized by academics and scientists as being, ill planned, little thought about, too ambitious and too late.

From the discussion above it may have become obvious that Pakistan is an underdeveloped country. Successive governments have failed to develop the enormous potential which Pakistan possesses in her vast land, varied geography, and mild climate, fertile soil, largest collection of snow clad mountains and glaciers and industrious teeming million. She has remained wedded to the mold in which colonial power left her in; producer of cotton, rice, fruits and vegetables for international market. Although Pakistan has enjoyed a respectable growth rate of 5-6 per cent over her entire period of existence, this rate is but the average for most developing countries emerging out of colonial domination. Our ranking among the forty two poorest countries in the world has more or less remained static. In fact many countries have left us far behind. How can we get out of our state of underdevelopment? I think by making optimum use of our advantages and breaking out of the impasse with maximum use of science and technology we can.

After nearly sixty years, the number of qualified scientists in Pakistan is too small to make any significant contribution. Furthermore, scientists are not supported with necessary equipment and other ancillary staff. It is therefore unrealistic to expect that they will make an impact. Scientific R & D is a must for any country aspiring to be a respectable member of the world comity of nations in the coming century. While we have lost a lot of precious time a beginning can still be made and desired results achieved in reasonable time frame if adequate resources are set aside for the purpose. There is that vast experience of other nations to learn from. If other nations can transform themselves into modern industrial ones with the help of science so can we.

Briefly put, first we will have to develop science and scientific manpower under a well thought out education policy and a policy for science. Next we ought to plan to use science in a well defined manner for the achievement of certain desirable social goal (full immunization, full literacy, safe water and sewage for all, electricity in every home using solar, wind, biomass, geothermal and tidal waves). Finally we ought to integrate science in our national development planning to become a prosperous country.