How to be an Asian Tiger

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Abstract

In 1995 the Republic of Korea (ROK) was officially admitted to the Organisation for Economic Cooperation and Development (OECD). This organisation groups together industrially developed countries of the world. Recently, the World Bank has also released a study of China that predicts that China is going to become the second biggest economy in the next fifteen years if its economic growth follows the pattern of the last fifteen years. ROK is the only country from among the developing countries to join the ranks of the developed industrialised countries in the last thirty years. However, it is still a small country compared to China. Hence when China completes its transformation into an industrialised country the whole world will be affected.

How did South Korea achieve such an accelerated transition to prosperity? What measures were adopted by the Chinese leadership that has allowed China to grow so rapidly? There are many factors that have been cited to explain Korea's miracle, and rapid Chinese growth. However, In the following we will highlight the role that education, science and research and development (R&D) have played in their success.

General prosperity with mass consumption has been achieved in the present century only in those countries that have transformed themselves from agrarian to industrial societies. They rely on massive industrialisation, mass production and mass consumption. They build huge power plants, country wide electricity grids, gas and oil pipe lines, refineries, dams, highways, ports, airports, huge mechanical, chemical, and electrical complexes. These industries use enormous amounts of energy and material and are generally based on the exploitation of science and technology (physics, chemistry, civil, mechanical, electrical and chemical engineering) generated over the last hundred and fifty years.

While industrialising, these societies educate all their citizens, banish illiteracy, provide schooling to all their children and youth (up to 18 years) and generally promote education and research. The modern knowledge system, with its public schools, colleges, universities and research institutions is the product of such societies. They generate new knowledge at an exponential rate, thus doubling it 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 percent or more of gross national product[1]. The productivity and efficiency of the worker increases continuously. Even agriculture gets totally mechanised and science based. It uses massive inputs of chemical fertilisers, pesticides, high yielding varieties of seeds, agricultural machinery, tube wells, sprinklers, canals, head works, bridges and dams.

Developed state of science is reflected in production of large number of books, journals and research papers. In 1993, for example UK, China, ROK and India produced 14003, IS559, 6913 and 1396 new titles respectively dealing with science and technology related subjects. USA produced over fifty thousand. In comparison Pakistan in 1993 produced just 94 new titles[2] on science and technological subject. Most of the three hundred new titles which appear every year in Pakistan relate to either religion or literature, a situation reminiscent of 14th century Europe. All this seems in total contradiction to our claims of achieving world standards in uranium enrichment, rocketry, lasers etc. Unfortunately, the real situation is far from satisfactory. Of the over half a million scientific research papers published annually all over the world, the Pakistani share is only 0.08 percent. India's share in comparison is nearly 30 times bigger[3].

Relation between Education, Science & Development:

It is an empirical observation that the state of development of a country as represented by its Gross Domestic Product (GDP), is directly related to the amount of resources the country devotes to scientific research and development (R&D).

The OECD Experience

Take the case of the OECD countries. These include 17 countries of Western Europe, besides Canada, USA, Australia, New Zealand, and Japan. In 1993 North America, EC and Japan together spent over 382,219.8 million dollars on scientific R&D, They also employed a total of 2,413,372 R&D researchers in the same year[4]. In 1990, these countries also filed patents for over one and quarter million new scientific and technological

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[1] *UNESCO YearBook 1995.*
[2] *UNESCO YearBook 1995.*
[3] Science In Pakistan; Nature, Vol. 376 - 24 August 1995
[4] *Main Science And Technology Indicators, 1995*. Organisation Economic co-operation and Development, Paris, France.

ideas and products. They held among themselves 98.2 percent of all European and 96.3 of all US patents in 1993[5].

OECD countries produced over seventy nine percent of the world gross products and services, notwithstanding the fact that their population is just 15 percent of the world total. Let me emphasise the point even further.

Research and development activities produce new knowledge and new products and services. Let us take a few examples from the last fifty years. The transistor was discovered just after the Second World War in Bell Laboratory owned by the giant, American Telegraph and Telephone (AT&T). Within twenty years it became an indispensable part of every electronic device. Microprocessors were developed in 1971, soon they were at the core of all automated devices and machines. Micro electronic industry in the USA had a sale of over 77 billion dollars in the first six months of 1997. The computer was developed in the mid 40s. Personal computers appeared in 1975. Now these computers are found in every office and household in developed countries. The computer industry in the USA alone had a sale of over 171 billion in the first six months of 1997. The Laser were developed in the mid 50s. Now they are found in every compact disk player. They are extremely useful tools in a surgeon's hand and dentist's drill machine. The USSR launched its first satellite in 1957. Within six years the first communication satellite COMSAT went up. Now satellites help in communication as well as remote sensing in a routine manner. The dish antenna on rooftops every where is a striking example of the wide use of satellite communication. The telecommunication industry in the USA alone had sales exceeding 128 billion dollars in the first six months of 1997. The helical structure of DNA was discovered in 195 6. Now this discovery has led to a multi billion dollar bio-technology industry. Numerous examples from other branches of science can also be given. In the last fifty years the exploitation of new scientific discoveries has given rise to multi-trillion dollar industries. The value of scientific knowledge and research and development (R&D) activities just cannot be overemphasised.

Research and development activities are undertaken by highly educated scientists, engineers and ancillary staff. These are usually the product of a country's education system, schools, colleges and universities. European countries that first adopted the industrial system of production in the late 18th and early 19th centuries understood the importance of education for the maintenance and development of industrial society. They introduced a universal elementary education system that has now been

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5 *Main Science And Technology Indicators, 1992*. Organisation Economic Co-operation and Development, Paris, France.

extended to all 18 year olds. They created a strong research based university system. This example was also emulated by the USA and other emerging industrial countries such as Japan. All OECD countries now have universal literacy and universal school education. They also provide college and university education to over half of their adults. In Canada all adults and in the USA 81 percent of all adults were enrolled in higher education institutions in 1993. OECD countries spend on the average over 5 percent of their GDP on education. This has allowed them to create a highly skilled workforce and highly qualified teams for scientific research and development work.

In 1995, the USA is estimated to have had over 8 million people with scientific and technical degrees. This number has been reached through exponential growth from around 1,00 in 1800 AD. It grew to 16,000 in 1860 AD and 128,000 in 1905 AD, 1,024,000 in 1950 AD, 2,048,000 in 1965 and 4,096,000 in 1980. US scientists and engineers publish over a quarter million research papers every year. In addition US scientists, social scientists and writers also publish over fifty thousand new titles every year. US scientists and engineers are the product of a highly developed US educational system. The US spends nearly five percent of its GNP on education[6].

Since the Second World War the USA has continuously spent more than any other country on science and technology. As a result the scientific leadership in the world has passed from old established industrial West European countries to the USA, This is reflected in the awards of Nobel prizes to scientists belonging overwhelmingly to the USA year after year. The USA also leads in the development of new scientific and technological inventions. The value which is accorded to science in the USA can be appreciated by the fact that every fifth US citizen is a degree/diploma holder in either science or engineering subjects. The increasing use of science has allowed less than 3 percent of the US labour force to produce all the diverse agricultural products in the USA[7] Similar trends are also visible in industry. Far less manpower is employed in US industry today to produce far more goods then forty years ago. This has been made possible by increasing the use of science in the production processes. On the average the USA spends more than 2.8 percent of her Gross National Product (GNP) on scientific R&D.[8] This has enabled the USA to emerge as the leader in the production of new scientific and technological products. It is the. only country in the world that has a positive balance of payments in technology.

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[6] *UNESCO YearBook l995*

[7] *World Development Report 1997*. World Bank, OUP.

[8] *World Science Report 1993*. UNESCO, Paris, 1995.

It spent a hefty 167010 million dollars on scientific R&D in 1993[9]. There are over half a million PhDs employed in its industries, academic and research institutions[10]. In the year 1995 USA had a GDP in access of 6,9J2,020 million dollars[11]. It was also the largest exporter of goods and services in the world. It also had a surplus of 12,647 million US dollars in technology transaction of 17,935 in the year 1990[12].

Japan, the second largest economy in the world with a GDP of nearly 5,108,540 million dollars in 1995[13], was a poor underdeveloped agrarian country in the last century. It decided in 1869 to catch up with the rest of the developed world. The emperor proclaimed that "Knowledge shall be sought throughout the world so as to strengthen the foundation of imperial rule". Consequently, it has spent lavishly on education to develop its human manpower resources. It recruited foreign teachers and scientists in the first stage. It sent out her own students for training in the universities of Europe and the USA. By the beginning of this century it had developed its own higher education system with colleges and universities with the help of academics trained abroad and within the country. It continued to send students and scientists. Its adoption, cultivation and promotion of science for over a hundred and thirty years has borne fruit. It has spent over 3 percent of its GDP on scientific R&D in recent years.[14] This has given it an undisputed leadership in most manufactures, especially of an electrical/electronic nature. Its citizens now enjoy the highest of living standards in the world. It has become the second largest economy in the world after the USA.

Germany, France and U.K., the third, fourth and sixth largest economies in the world, spend over one hundred billion dollars on scientific research and development every year[15].

Russia which was the least developed country in Europe at the beginning of the 20th century producing only ten percent of the US industrial product, had before its present troubles, advanced to produce

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[9] *Main Science And Technology Indicators, 1995*. Organisation Econornic Co-operation and Development, Paris, France.

[10] *Main Science And Technology Indicators, 1992*. Organisation Economic Co-operation and Development, Paris, France.

[11] *World Development Report 1997*. World Bank, OUP.

[12] *Main Science And Technology Indicators, 1992*. Organisation Economic Co-operation and Development, Paris, France.

[13] *World Development Report 1997*. World Bank, OUP.

[14] *World Science Report* 1993 UNESCO, Paris, 1995.

[15] *Main Science And Technology Indicators, 1992*. Organisation Economic Co-operation and Develooment. Paris. France.

almost as much as the USA by the early 80s. It has achieved the status of a superpower by consistently cultivating and promoting science. Russia has the largest stock of scientists and engineers in the world and till recently used to spend the largest percentage of its GNP on science, which was nearly 4 percent in 1986. It accounted for nearly one-fifth of the world industrial output and turned out more steel, cast iron, rolled metal, coal, oil and gas, iron ore, cement and mineral fertilisers than any other country in the world. In addition it was the second largest producer of electricity, engineering products and cotton fibre in the world in 1986. Despite all talk of underdeveloped agricultural production the USSR was still the third largest producer of grains and legumes in the world in the same year. Once Russia is able to sort out its problems related to transition to a free market economy, its well developed science will allow it to leapfrog to prosperity.

The USA, Japan, Germany and other OECD countries have now become post industrial information based societies. Their wealth depends on the generation, dissemination and processing of information.

The group of newly industrialised countries of the Far East comprising the Republic of Korea, Taiwan, Singapore, Hongkong together account for less than one percent of world population. However, their share in global production is nearly two percent[16]. These countries have in the last thirty years increased their share of global production from almost zero to the present impressive figure. One of these countries, the Republic of Korea has even been admitted to the OECD.

Planning for Development:

So far we have just given the examples of the two countries which have achieved the status of superpowers in the world in the last forty years. The USA has followed the capitalist path of development, while the USSR has used central planning for its development. Both countries have however used science for development in a planned manner. The USA launched the largest planned effort during the Second World War to develop the atomic bomb. Thousands and thousands of scientists and engineers were employed at numerous laboratories. Successful explosion of the bomb in 1945 demonstrated to all nations, irrespective of their social and political systems, that science can be used in a planned manner to achieve desired goals. Similar to the Manhattan Atomic bomb project in the USA, other projects were launched in the UK and Germany to develop rockets, radar and a he of other devices.

[16] *Main Science And Technology Indicators, 1992*. Organisation Economic Co-operation and Development, Paris, France.

After the Second World War almost all governments and industrial concerns have established institutions to use science for development in a planned manner. In the early 60s the USA launched a concerted effort to put an American on the moon. Massive research and development efforts by the National Astronomic Space Agency (NASA) was successful in the effort and an American was successfillly placed on the surface of the moon in 1969. In 1992, Watson, the co-discoverer of DNA structure launched a massive global scientific research and development protect, the Human Genome Protect involving 9000 scientists in 36 countries, to map the entire 6 billion atom sequence of the human genome. The protect is expected to be completed by the year 2002. On completion it will allow the identification of every characteristic of the human body with one gene or the other. It will be analogous to the preparation of a skeletal map that one finds in an anatomical laboratory. This will help in developing processes and drugs through genetic engineering that will fix genetic malfunctions and cure diseases that have remained incurable till recently.

Planning for Development: China and Korea

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. Korea and China are representative examples. What Britain achieved in two hundred years, Japan achieved in a hundred years. ROK achieved that in just a generation. China is next in line to achieve that in the next fifteen years for a fifth of the world population.

The Republic of Korea, a war ravaged agrarian economy with a GDP of less than 3 billion US dollars in 1965 and listed with Pakistan among the poorest countries, has now graduated in thirty years to the ranks of high income countries along with other OECD countries. Its GDP in 1995 was a hefty $ 455,476 million[17]. So Korea has already made a transition to an industrial society. Agriculture now constitutes only 7 percent of its GDP, while industry and services contribute the rest.

From the very beginning ROK has invested heavily in developing its human manpower potential through education. Korea was occupied by Japan whose colonial rule ended only in 1945. At that time only two percent of the Korean population over 14 years of age had completed secondary school, and the illiteracy rate stood at 78 percent. Korea was then engulfed in a civil war situation that only ended with the division of the country into two

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[17] *World Development Report 1997*. World Bank, OUP.

parts in 1953. The southern part was named the Republic of Korea, while the north was called Democratic Republic of Korea. Since 1953 ROK has achieved remarkable results in educating its population. In primary level schools the enrolment increased five times so that by the year 1970, all the school-going children were being enrolled in schools. Secondary school enrolment increased more than 28.5 times between 1945 - 1986, while enrolment in colleges and universities increased almost 150 times during the same period. ROK was furthest in the direction of more education than would be expected, given her GNP per capita. That is, with a per capita income of $ 90, ROK's educational achievement stood fairly close to the normal pattern of human resource development for a country with a mean per capita GNP of $ 200. When ROK's per capita GNP rose to $ 107, its level of human resource development was equivalent to that of countries with a GNP per capita of $ 380[18].

As a result, ROK surpassed other newly industrialised countries (NICs) by almost all indices of educational attainment. Thus in the late 1970s ROK had the highest number of secondary students as a percentage of the secondary age population; engineering students as a percent of total post secondary age population; scientists and engineers per million of people; and scientists and engineers in research and development per million of people. By the early 1980s over 95 percent children were enrolled in middle level schools. And over 70 percent of boys and girls were attending high schools. By the mid 1970s the illiteracy rate had become insignificant. Between 1975 and 1990, ROK tripled its university enrolments and in 1990, 36 per cent of Korea's youth in the 20-24 year old age group were attending universities. By the early 1990s, 93 per cent of its boys and girls were enrolled in secondary schools. Forty eight percent of its youth was being enrolled in institutions of higher learning by 1995[19]. Korea now boasts of having 1343 scientists and engineers per million of population. Between 1981-91 Korean gross expenditure on research and development (GERD) grew each year by nearly 25 percent[20]' Such foresight in the development of human manpower has paid off handsomely. ROK has multiplied its exports nearly seven times in a fifteen year interval (1980-95), ninety three percent of its exports consisting of manufactures[21]

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[18] Kim Linsu: "Technological Transformation in Korea and its implication for other Developing Countries", Development & South - South Cooperation, Vol. IV, No. 7, Dec. 1988, (Ljiubljiana, former Yugoslavia).
[19] *World Development Report 1997*. World Bank, OUP.
[20] *World Science Report 1993* UNESCO, Paris, 1995.
[21] *World Development Report 1997*. World Bank, OUP.

China had achieved universal primary education for its children by early 1970. By the end of 1993, 51 percent of its girls and 60 percent of its boys were enrolled in high schools[22]. It has also expanded its higher education system greatly. 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 have remained at 40 per cent of the total undergraduate enrolments and 63.7 per cent of the postgraduates and the proportion of doctoral students is even higher[23]. The production of a vast number of science and technology graduates has encouraged the cultivation of science in a big way. In 1993 it employed altogether 2,426,300 S&T personnel (not including the support staff in S & T service departments). Of these 1,484,300 were scientists and engineers. In the same year the number of R&D scientists and engineers reached 598,000[24]. The vitality of the S&T system in China has been due to a continuous influx of new talent from its institutions of higher learning as well as scientists and engineers who return after their education and training from abroad. Their number runs into hundreds of thousands. 12,9000 Chinese students were studying abroad in 1992[25].

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"[26].

One consequence of this is that industry in China has grown at the rate of 10 percent between 1965-80 and at 12.4 percent from 1980-88 and at a hefty rate of 18.5 between 1990-95. Its share in the GDP has risen to 48 in 1993[27], while that of agriculture has decreased from 34 percent in 1970 to just 19 percent in 1993[28].Chinese exports have jumped from 18,100 in 1980 to 148,797 million dollars (nearly an eight fold increase in 15 years, 81 per cent of the exports consist of manufactures!). China is thus fast turning into a predominantly industrial society.

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[22] *World Development Report 1997*. World Bank, OUP.
[23] *World Science Report* 1993 UNESCO, Paris, 1995.
[24] *World Science Report* 1993 UNESCO, Paris, 1995.
[25] *World Science Report* 1993 UNESCO, Paris, 1995.
[26] *World Science Report* 1993 UNESCO, Paris, 1995.
[27] *World Development Report 1997*. World Bank, OUP.
[28] *World Development Report 1995*. World Bank, OUP.

Development in Pakistan

What has been Pakistan's performance? How has Pakistan fared the past fifty years? Pakistani society is predominantly agrarian. However, it is being slowly transformed into an industrial society. Industrialisation in Pakistan has proceeded at a steady pace, increasing its share in Gross rational Product from just under two percent in 1950 to 20 percent in 1965 and to 24 percent in 1988. Industry has grown at an average rate of 6.4 percent between 1965 and 1980 and at a rate of 7.2 between 1980 and 1988. This slow but steady growth has raised the share of Industry in the GDP. In 1993 industry contributed 25 percent while services (trade, commerce, banking, insurance etc.), provided half the total Gross National Product. The share of the agriculture sector in Gross Domestic Product has been steadily decreasing from 37 in 1970 to 26 percent in 1995. However, the share of industry in the GDP has remained more or less constant at 25 since 1980. In fact it even declined in 1995 to 24 percent[29]!

Despite impressive progress in the last 50 years, Pakistan's position in the comity of nations is far from impressive. Pakistan is a country of over \25 million people; of which three fourths are unable to read or write; seventy percent of whom do not have access to safe drinking water; half of whom live in one room houses, each room accommodating as many as six people on the average; two thirds of the houses in which Pakistanis live are kutcha built with unbaked mud bricks; eighty seven percent of the houses do not have piped water; two thirds of the houses do not have separate bath rooms; eighty percent of the houses do not have a separate latrine[30,31].

A Pakistani man on the average lives for only 61 years, compared to 74, which is the average for developed countries. Pakistani women have the added "distinction', that on the average their spouses out live them, contrary to the experience of most other countries, developed as well as developing. The child mortality rate in Pakistan is on the average eight times higher then in developed countries. The rate of death among women: it childbirth in Pakistan is almost thirty three times higher than that prevalent in developed countries[32].

The situation concerning educational facilities available to Pakistani children and youth is very grim. The developing countries on the available, provide primary education facilities to over hundred percent children of school going age. In Pakistan however, primary school facilities are available

[29] World Development Report 1997. World Bank, OUP.

[30] Alam. M. Anis, "The First Wave In A New Age" Daily The NEWS, Jan. 3, 1997.

[31] Alam. M. Anis, "A Social Place For Science", Daily The NEWS, Jan.10, 1997.

[32] World Development Report 1997. World Bank, OUP.

to just over fifty percent. These facilities have increased from 40 percent in 1965 to just 44 percent in 1986. In India and China taken together the facilities were already fairly high at 83 percent in 1965. The facility of secondary school education is available to only eighteen percent of our youngsters compared to an average of 39 for the developing countries in general. Tertiary level education (college and university level education) essential for the economic well being and technological uplift of any country benefits barely two percent of our young men and women. In developed countries nearly forty percent of the corresponding age group is admitted to the college and university level educational institutions[33]!

Science & Technology in Pakistan

According to the data available in various government publications, there are over 140 government scientific research establishments in Pakistan. Some of the well known scientific institutions are, Pakistan Atomic Energy Commission (PAEC), Qadeer Khan Research laboratories, Space and Upper Space Atmospheric Research Organisation (SUPARCO), Pakistan Agricultural Research Council (PARC) Pakistan Medical Research Council (PMRC), Pakistan Council of Scientific and Industrial Research (PCSIR). The Pakistan armed forces also have research and development laboratories of their own. The best known among them is Defence Science and Technology Organisation (DESTO). These laboratories have made a modest contribution.

PAEC achievements in nuclear medicine, non destructive material testing and development of new seed variety of cotton have been well publicised. PAEC has also served as a refuge of highly qualified physicists who could not be absorbed elsewhere. The Qadeer Khan Laboratories contribution to uranium enrichment have made Pakistan known the world over. PCSIR development of a pesticide and numerous import substitution processes has also been acknowledged.

Dependence on foreign Science & Technology

However these organisations have not contributed significantly to the scientific and industrial development of the Pakistani nation. .After fifty 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 the economy, agriculture, has also come to depend heavily on imported pesticides, fertilisers, hybrid high yielding varieties of seeds and agricultural machinery (harvesters, tractors and other

[33] World Development Report 1997. World Bank, OUP.

machinery). This massive input of science in agriculture has allowed a steady increase in the yield of various crops. However, the productivity of our agriculture with some exceptions is still far below world standards.

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

Our industry is mostly based on imported plants and raw materials. Even for our defence 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 the national economy are many. Successive Pakistani governments and Pakistani society in general have not clearly understood the role of scientific R&D in national development. They have therefore never made a 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. This is borne out by the following facts.

Of the 137 scientific research establishments for which data was compiled by the Pakistan National Science Council in 1982, 133 institutions together employed only 109 PhDs. 66 of these had no PhDs on their staff, 15 organisations had only one Ph.D., 19 had only 2 PhDs and 8 had three PhDs among their staff. Only PCSIR laboratories had 106 PhDs working in its three laboratories in Karachi, Lahore and Peshawar. PCSIR laboratories have contributed to import substitution in a small way. The situation has deteriorated in most of these institutions due the retirement of senior staff with little or no efforts to replace them with equally if not better qualified staff[34].

The only research organisation that has been funded adequately is Pakistan Atomic Energy Commission and the laboratories run by Dr. Qadeer Khan. But even they have not contributed any thing to the urgent problems of power shortages. The only functioning atomic power plant in Pakistan is a Canadian supplied nuclear reactor of 137 megawatt capacity. This power plant has worked intermittently since 1972 and almost always operated at lower than its peak capacity.

From the discussion above it may be obvious that Pakistan is an underdeveloped country. Successive governments have failed to develop the enormous potential which Pakistan possesses in its vast land, varied geography, mild climate, fertile soil, largest collection of snow clad mountains and glaciers and industrious teeming millions. She has remained wedded to the old order in which colonial power left it in; producer of cotton, rice, fruits and vegetables for the international market. Although Pakistan has enjoyed a respectable growth rate of 5-6 percent over its entire period of existence, this rate is but the average for most developing countries emerging from 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 extricate ourselves from this 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, it is possible.

Possible Course of Action

Successive governments have failed miserably to evolve and implement any policy for the development of science. The question of using science for national development just does not concern Pakistani governments. Pakistan spends less than 0.2 percent of its GNP on science. This is about one third the average for developing countries as a whole and only one fifth of what our biggest adversary India spends on science. However, in a recent article in The British science journal Nature, Ehsan Masood quoting an unpublished 1993 UNESCO World Science Report claimed that Pakistan spends one percent of its GDP on scientific R&D. However, knowing the lamentable situation of the R&D establishment in the country the writer is quick to comment. "The 64-million rupee question

[34] Alam. M. Anis, 1988. Forty Years of Science & Technology in Pakistan and India: Comparative Survey: In Proceedings of PASSP Seminar on "Forty Years Of Science & Technology in Pakistan", Karachi, Nov. 88.

is: who spends the rest of Pakistan's not-insubstantial science budget?" According to the latest World Bank's *World Development Report* 1997, 1 per cent of Pakistan's GDP of 1995 comes to 606.49 million US Dollars[35]!

Pakistani science has therefore not developed as it should have. The only period during which science received any attention by the government was the period when Prof. Abdus Salam was advisor to the President of Pakistan on scientific affairs. During his tenure a large number of scientists were trained and a number of scientific institutions like PAEC and SUPARCO were strengthened. Since his departure many new institutions have been created, but they have lacked a sense of direction and leadership. Institutions have been created for providing jobs to scientists not to accomplish a well defined task. A steady decline in quantity and quality of Pakistani science can be detected through out the 80s. The confusion and loss of direction of that period is now manifesting itself in a totally demoralised scientific community.

After nearly fifty 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 much precious time, a beginning can still be made and desired results achieved in a 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, we will first have to develop science and scientific manpower under a well thought out policy for science. Next we ought to plan to use science in a well defined manner for the achievement of certain desirable social goals (full immunisation, frill 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[36].

Let us now examine the structure and volume of production in Pakistan from a global and regional perspective. Pakistan's population

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[35] Science In Pakistan; *Nature*, Vol. 376 - 24 August 1995

[36] Alam. M. Anis; 1988. "Status Of Science & Technology policies for SAARC Countries", in Proceedings of the SAARC Workshop on Science Policy, Ministry of Science & Technology, Government of Pakistan, Islamabad.

constitutes slightly over two percent of the world population of nearly five billion. But it produces just one quarter of one percent (0.25 %) of global production. In comparison, less than fifteen percent of world population living in the highly industrialised countries (USA, Canada, Japan, Germany France, UK, Sweden, Holland, Italy, Austria, Switzerland, Australia, New Zealand, Ireland) produce over sixty five percent of world production (industrial, agricultural, mineral, services). There are several developing countries with sizeable gross domestic products in billions of US dollars. In decreasing order of size they are China (697.647), Brazil (688.085), India (324.082), Korea (455.476), Argentina (281.060), Indonesia (198.079) Turkey (164.789), Thailand (167.056), South Africa (136.035), Philippines (74.180), Malaysia (85.311) in 1995. In comparison, Pakistan's Gross Domestic Product in that year stood at 60.649 billion dollars. Now many developing countries with a population much smaller than that of Pakistan have much bigger Gross Domestic Products. Malaysia, Philippines, Thailand, Turkey, Colombia and Argentina. Developed countries such as the USA, Japan, Germany, France, Italy and the UK have Gross Domestic Products of 6952, 5108, 2415, 1536, 1086, and 1105 billion dollars respectively in the year 1995. It is in this world scenario that we are to compete.

Table 1: Gross Domestic Expenditure on research and development (GERD),
Gross Domestic Product (GDP) and GERD/GDP ratio for different areas of the world, 1992

	Gerd[1] (Billion US $s)	*GDP[1] (Billion US $s)*	*Gerd / GDP (%)*
Eurupean Union[2]	117.6	6079	1.9
EFTA[3]	5.47	233	2.3
USA	167.01	5953	2.8
Canada	8.13	537	1.5
Japan	68.31	2437	2.8
Australia & New Zealand	4.12	341	1.2
OECD	*370.64*	*15580*	*2.4*
NICs[4]	10.73	824	1.3
China	22.24	3155	0.7
India	7.1	940	0.8
Pakistan	2.98	298	1.0
Central and Eastern European Countries	2.89	188	1.5
Commonwealth of Independent States[5]	4.13	496	0.9
Israel	2.89	188	1.9
North Africa	0.72	160	0.4
Middle & near East	3.11	598	0.5
Subsaharan Africa	1.09	245	0.4
Other countries in Far East	0.69	982	0.1
World Total	428.58	24295	1.8

1. Calculated in purchasing power parity (PPP)
2. European Union: 15 member countries of the Union as of 1995: Austria Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden and UK.
3. EFTA: the four member countries as of 1995: Iceland, Lichtenstein, Norway and Switzerland.
4. NICs: Newly Industrialised Countries as of 1995 Korea, Hong Kong, China (Taipe), Singapore.
5. CIS: Republics of former USSR excluding the Baltic states.

Source: World Science Report, 1993 and OECD Indicators.

Table 2: R&D Scientists and Engineers and Population ratios for different areas of the World. 1992

	R&D Scientists & Engineers (SE) ('000)	*Population (Millions)*	*R&D SE Per thousand population*
Eurupean Union	740.9	369.0	2.0
EFTA	32.6	11.9	2.7
USA	949.3	257.5	3.7
Canada	64.6	27.8	2.3
Japan	511.4	124.8	4.1
Australia & New Zealand	48.5	21.2	2.3
OECD	*2347.3*	*812.2*	*2.85*
NICs	136.7	92.5	1.5
China	391.1	1205.0	0.3
India	106.0	887.7	0.1
Pakistan	6.626	~120	0.05
Central and Eastern European Countries	285.5	131	2.2
Commonwealth of Independent States	452.8	283	1.6
Israel	20.1	5.4	3.8
North Africa	81.6	219.7	0.4
Middle & near East	117.4	465.9	0.3
Subsaharan Africa	176.8	482.6	0.4
Other countries in Far East	60.3	513.5	0.1
World Total	4334.1	5563.1	0.8

Source: World Science Report, 1993 and OECD Indicators

Table 3: Scientific Production, measured by publications, 1993

	World share 1993 (%)	*1993 index (base 1982 = 100)*
Eurupean Union	31.5	107
EFTA	1.7	100
USA	35.3	96
Canada	4.5	108
Japan	8.1	119
NICs	1.4	412
China	1.2 (12th position in the world)	347
India	2.1	83
Pakistan	0.08	200
Central and Eastern European Countries	2.3	87
Commonwealth of Independent States[5]	4.8	56
Israel	2.89	90
North Africa	0.4	110
Middle & near East	0.6	186
Subsaharan Africa	0.8	89
Other countries in Far East	0.1	113
Australia & New Zealand	2.7	94
World Total	100	

Source: *World Science Report*, 1993 and OECD Indicators.

Table 4: Technological Production, measured by Patents granted in Europe and the USA, 1993

	European Patents			
	World Share 1993 (%)	*1993 (base 987 = 100)*	*World share 1993 (%)*	*1993 (base 1987 = 100)*
Eurupean Union	45.4	91	18.6	76
EFTA	3.2	86	1.5	73
USA	27.3	103	48.7	105
Canada	0.8	82	2.3	105
Japan	20.9	129	25.0	111
NICs	0.5	241	1.3	189
China	0.0	--	0.1	153
India	0.0	--	0.0	--
Pakistan	--	--	--	--
Central and Eastern European Countries	0.2	58	0.1	41
Commonwealth of Independent States[5]	0.2	174	0.1	54
Israel	0.4	124	0.4	114
Australia & New Zealand	0.6	59	0.5	79
World Total	428.58	24295	1.8	1.8

Source: *World Science Report* and OECD Indicators.

Table 5: Technological Production and its Evolution in the triad, measured by European and US Patenting, 1987 – 1993

	World Share World Share (%)		*US patents World share (%)*	
	1987	*1993*	*1987*	*1993*
Eurupean Union	49.9	45.4	24.4	18.6
USA	26.8	27.3	46.3	48.7
Japan	16.2	20.9	22.5	25.0

Chinese researchers were granted 62000 patents in China.

Source: *World Science Report* and OECD Indicators.

Table 6: Scientific Production per discipline measured by percentage share of publication, 1993

Scientific Disciplines *Areas*	*Clinical medi-cine*	*Bio-medical research*	*Biolo-gy*	*Chem-istry*	*Phy-sics*	*Earth Scien-ces*	*Engin-eering Scien-ces*	*Mathe-matics*	*All discip-lines*
Europe	41.0	36.8	31.5	36.9	34.4	32.7	29.6	38.0	36.5
North America	41.4	44.9	43.6	27.9	32.8	45.5	44.0	39.7	39.8
Europe + N. America									76.3
Japan & NICs	8.1	9.5	7.6	14.0	11.7	4.1	12.6	6.3	9.5
Commonwealth of Independent States	1.4	2.9	2.2	9.9	10.7	5.7	4.3	4.8	4.8
Muslim countries	0.9	0.4	1.2	1.7	0.8	1.1	1.6	1.2	1.0
Latin America	1.3	1.3	2.5	1.3	1.9	2.1	0.9	1.6	1.5
Subsaharan Africa	1.2	0.5	2.1	0.5	0.3	1.2	0.4	0.6	0.8
Other countries in Far East	1.6	1.4	3.3	6.1	6.1	3.5	4.8	5.6	3.4
Australia & New Zealand	3.2	2.3	6.0	1.7	1.3	4.1	1.8	2.3	2.7
China	Chinese scientists and engineers published 20178 scientific papers listed in SCI in 1993.								
Pakistan	Pakistani scientists published 2062 scientific papers listed in SCI during 1990-94								

Source: *World Science Report* and OECD Indicators.

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