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Science, Technology and Innovation Policy Review

The Islamic Republic of Iran

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PREFACE

UNCTAD carries out Science, Technology and Innovation Policy Reviews, or STIPs, in order to assist interested member States in formulating policies and strengthening the role of science and technology institutions in building national productive capacity and international competitiveness.

The Science, Technology and Innovation Policy Review of Iran was initiated at the request of the Iranian Ministry of Science, Research and Technology (MSRT), and undertaken in close cooperation with the United Nations University's Institute for Innovation and Technology (UNU/INTECH) in Maastricht, and the United Nations Development Programme (UNDP), which also financed the project.

The report was prepared by a team of international experts, led by Lynn Mytelka and comprising Tirso Saenz, Svend Otto Remoe, Prasda Reddy and Fulvia Farinelli, UNCTAD project officer. An additional input was provided by Rustam Lalkaka, Mongi Hamdi and Taffere Tesfachew. Stephen Hatem provided production assistance. A preliminary draft of the report was presented at a national workshop in Tehran in November 2003, involving the international team of experts, government representatives, the business community and other stakeholders. The report and recommendations were finalized under the overall responsibility of Khalil Hamdani, UNCTAD.

The national counterpart, MSRT – Deputy Minister, Dr. MiliMonfared, and in particular the Iranian Research Organization for Science and Technology (IROST), provided substantive, logistic and financial support. The background reports were prepared by a team of local experts at the MSRT, at the Ministry of Economic Affairs and Finance, Shirkavand, at the National Research Center for Genetic Engineering and Biotechnology, Sanati, and at the National Petrochemical Company, Taeb. At IROST, H. Salar Amoli, H. Hajihosseini, E. Moeini, F. Abasi and Homa Sharafi provided additional inputs at various stages of the project. Ali Farzin was the counterpart in the UNDP Office in Tehran.

It is hoped that the analysis and recommendations of the review will promote awareness of policy options to strengthen technological capabilities, and provide a basis for implementing an effective innovation strategy.

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EXECUTIVE SUMMARY

Iran has pursued a development strategy of self-reliance with some success. Endowed with abundant oil and natural gas resources, Iran did not face an import constraint. Yet, Iran adopted an import substitution policy and used its oil revenues to acquire foreign technologies to industrialize. Iran is today a middle-income developing country, with a significant industrial base, a relatively well-developed science and technology infrastructure and good human development.

However, unlike other middle-income countries, Iran is still largely a natural resource-based economy. Diversification is an imperative, not only because natural resources are exhaustible but also because export success in world markets increasingly demands knowledge-intensive production and innovation-based competition. Above all, there is need to provide quality jobs for the 800,000 literate Iranian men and women that enter the labour market every year.

The shift to a more knowledge-based economy will require creating a national innovation system that can not only import and adapt technologies, but also improve upon them, innovate new technologies and diffuse them economy wide. There is need to better link the science and technology infrastructure to the needs of the productive sector generally, and in particular to build up capabilities in high technology areas such as biotechnology, petrochemicals and new materials. That is the central message of this report.

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In contrast to other developing countries with comparable technological capabilities, Iran's economy is still largely dependent on the primary sector. The agriculture and the oil and gas sectors together account for 30 percent of GDP; the industrial sector accounts for 23.4 percent (including water supply, electricity and gas). Domestic manufacturing industry has been built mainly through licensing of technology from abroad and in some cases through reverse engineering. Products are largely sold in the protected domestic market and tend to suffer from low quality (and high costs). Moreover, the manufacturing sector, to a large extent, continues to rely on imports for components and raw material (for example, the pharmaceutical sector). Adequate emphasis should be placed on simultaneously developing appropriate supplier industries, which was a practice followed by other countries such as India that followed import-substitution policies.

Although there is a commitment to move towards a market-oriented economy and development of the private sector, State-owned enterprises (which are mainly large enterprises) continue to account for much of the industrial sector. It is difficult to assess the exact contribution of private sector *per se*, but its contribution to GDP value-added is estimated at under 15 percent. The small and medium enterprises (SMEs), which form the backbone of economies worldwide, play only a small role in the economy. There is need for promotional policies for SMEs, and related measures to encourage entrepreneurship in Iran, such as provision of seed capital and venture capital, and the establishment of science and technology parks and business incubators with adequate funding and support services to assist start-up enterprises. The issue of establishment of property rights is still uncertain and discourages private entrepreneurship.

Iran's export base is narrow, relative to its industrial base and its technological capabilities. Manufactured exports account for only 9.3 per cent of total merchandise exports. With the exception of mining and metals where technological improvements have resulted in the production of export-quality products, the overall industry is not diversified sufficiently and is not in a position to compete in international markets. Iran lags behind others oil producing countries in producing/exporting value added petroleum products. Nevertheless, given its technological capacities, Iran could develop biotechnology, pharmaceuticals and petrochemical products into export champions within a reasonable time frame.

The main actors in the Iranian national innovation system are the government ministries, the research institutes/universities and the enterprises. The uniqueness of the system is that almost all the research institutes/universities and an overwhelming majority of the enterprises are State-owned. Largely due to the government ownership, there are close links between the research institutes/universities, enterprises and government. Other actors such as the business associations, business support organizations and consumer groups are very weak and play almost no role in the system. As a result, user-producer linkages are weak and innovation activities in Iran are not demand-driven. The absence of private enterprises that base their innovation strategies on conditions of demand and competition makes it difficult to derive larger economic benefits from innovation. Such larger benefits that Iran is not, presently, realizing would include opportunities for commercializing new products, emergence of spin-off enterprises and new entrepreneurs, etc.

Iran’s industrial sector lacks effective competition. Competition is the key driving force for innovation and technological change. The system of licenses and resource allocation (subsidies) ensures that there is only limited competition (that too mainly based on price) in vast majority of the industries. This lack of or limited competition does not motivate companies to develop new products or product features. Recognizing this the Government is gradually opening up the economy to competition, but the process is too slow.

A unique feature of Iran’s innovation system is the marginal role played by the foreign companies, with the exception of oil and gas industry. Foreign companies bring in new technologies in the form of new products, processes and management techniques. The local operations of foreign companies lead to spillover effects and diffusion of new technologies into wider economy. They also spur competition and motivate domestic companies to upgrade their technologies and innovate in order to compete. Government has established free zones where foreign companies can locate operations. However, for the wider diffusion of technologies into the whole economy that is a small move.

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Iranian authorities recognize the need for policies that will stimulate diversification, technological upgrading, learning and innovation. The Fourth Five-Year Plan 20005-

2009 places emphasis on the adoption of policies for enhancing innovation, internal and external sources of R&D and mechanisms for building technological and innovative capacity. The recent creation of a Supreme Council for Science, Research and Technology chaired by the President, and the establishment of a coordinating secretariat within the Ministry of Science, Research and Technology, provide a basis for overall goal and priority setting within an integrated innovation-based framework. In this context, Government should consider:

Designing an innovation strategy – Iran needs to design and formulate an innovation strategy, with clear and measurable short-term, medium-term and long-term objectives and programs. Such a strategy might focus on fostering learning and linkages, two weaknesses that are common to both the national and sector-level innovation systems in Iran. It is within such a framework that new system-wide innovation-based initiatives could be developed. These would combine the actions of diverse ministries, each of which, by setting sector-level goals and priorities and designing policy instruments.

Strengthening measures to support transparency and accountability – Knowledge and information flows provide the signals for both adaptive policymaking and technological innovation. To enhance such flows, within the shortest possible time, the government should set up a system for monitoring and evaluating policies and programmes, strengthen the collection of economic data and information on science and technology inputs and outputs and initiate periodic firm-level innovation system surveys.

Implementing sectoral innovation strategies – Iran could usefully apply the concept of 'technology-missions' successfully adopted by several countries, including Japan, the Republic of Korea and India in formulating such a strategy. This concept involves formulating specific measurable objectives to be achieved in a selected sector within a specified time and detailed plans to achieve these objectives. In the broader national system of innovation and within it the biopharmaceutical and the oil, gas and petrochemical sectors in particular, the following specific actions might be considered for priority attention.

Fostering research and technological capacity through joint ventures and licensing agreements - Licensing has been practiced in Iran as a means to produce a variety of products in the oil, gas and petrochemical sector as well as in pharmaceuticals for the domestic market, but incentives for learning through licensing and joint ventures have been few. This is related to the continued emphasis in Iran on production rather than on innovation as the core of the development process. But getting the most out of these agreements in the long term should warrant including them as major instruments in a national innovation policy and designing them accordingly. Data also needs to be collected on past licensing practices. This can take place through the merger of existing registries of licenses and joint ventures currently located in a large number of ministries. These data can form the basis for a restricted on-line distributed information system and make possible needed research into factors that have been a disincentive to learning through licensing and joint ventures in Iran and contribute thereby to an effective policy environment to deal with this problem.

Strengthening user-producer links - Innovation is fundamentally an interactive process and user-producer interactions are at the core of a dynamic innovation system. Users may be downstream enterprises, which are clients of upstream firms as in the link between oil and gas producers and petrochemical firms or petrochemical firms and downstream industries such as polymers, textiles and automobiles. Users might also be located in the service sector or in the ministries. The health care system, for example, is both a direct user of medical research and a consumer of drugs produced by pharmaceutical firms. Health care policies will thus have an impact on the selection of research directions to pursue and the choice of production techniques and sources of technology. In a well functioning innovation system, there is a critical need for linkages between the demand –side interests of users and both the knowledge and goods producing sectors. Frequently however, demand is only weakly articulated, though the need for information, know-how and embodied technology is needed to sustain competitiveness in a sector. Policies have a strategic role to play in strengthening these linkages.

Prioritizing SMEs - SMEs add flexibility to adjustment processes, create employment, strengthen local economies and are often leaders in innovation within high technology sectors. So, Iran should first 'map' the SME sector identifying strengths/weaknesses and select appropriate points of intervention. Next, Iran should formulate the policy and regulatory framework in consultations with the business persons and associations. Iran should also develop market-oriented business development services. Technical cooperation projects can be designed to transform state service agencies into contract consulting and research mechanisms. The services provided include entrepreneurship training, advisory and facilitation services, human resource development, business management, marketing, mentoring, counseling, networking, financial and personnel management, legal assistance, and export assistance.

Targeting the supplier industry - A policy aimed at supporting SMEs to develop and produce the inputs/components needed by the large state-owned enterprise at competitive levels will promote innovation and help in building up the support industries that can compete in the export markets. Lessons can be drawn from the success of automotive component manufacturers in countries such as Thailand and India in becoming global suppliers.

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Iran's large reserves of oil and gas resources provide a natural comparative advantage to produce high-value added petrochemicals not only for domestic use but also for global markets. Iran should tap this potential to become a major global player in the petrochemical sector. Although it has built up some capacity to produce petrochemicals, Iran continues to rely mainly on export of crude oil. Iran also imports a significant share of the oil products it consumes. Downstream industries, such as the detergent, rubber, plastics and paints, which are users of petrochemicals continued to import the bulk of their raw material needs until the early 1990s. But, with the completion of the upstream projects in 1992 there has been a sharp reduction in the import of petrochemical raw materials. In order to achieve a better recovery rate from its oil wells, and to build a competitive petrochemical industry that produces high value products, Government should consider:

Establishing a public service organization - The failure to derive higher value from natural resources stems to a large extent from the fusion of functions: policy-making, resource management and production under the direct control of a single organization. While policy-making should remain with government, the resource management function should be entrusted to a public service organization that operates under governmental regulations to optimise the exploitation of oil and gas resources. Iranian and foreign companies and joint ventures should concentrate on production activities, competing with their best available knowledge and technology.

Revising buy-back arrangements - The recent buy-back contracts were well received as a means to allow foreign oil companies to take part in the Iranian oil and gas activities while providing capital without ownership of resources. But, the system as it currently works provides disincentives to learning, technology development and optimal recovery of reservoirs over time. A revision of the current system to allow a longer time horizon for the contracted partner is needed. Then the foreign partner will be more willing to deploy long-term resources and conduct R&D. This will result in a higher recovery rate from its oil wells.

Developing performance and future oriented prioritization and selection criteria for R&D - The current combined system of strategic five-year plans and bottom up proposals from researchers is both inflexible and lacks strategic vision. For the petrochemical sector we propose development of a system that better distinguishes between short-term needs for the sector as such, and the long term needs of advanced research needed to develop advanced polymers and forward linkages to the end user industries. This includes the need to develop research programmes in co-operation with end-user representatives with performance or target-oriented objectives.

* * *

Iran has a fairly well developed pharmaceutical industry compared to others in the developing world. Iran has also been a successful in extending healthcare to the entire population, thanks to the availability and accessibility of medicines at affordable prices. However, only a few pharmaceutical companies have R&D capabilities to develop new products and processes. Their capabilities are mainly in developing new formulations and dosages. Even in the case of manufacturing of drugs much of the raw material is imported. With an improved petrochemical industry to provide raw materials and availability of a vast variety of flora and fauna, Iran has the potential to build up a globally competitive biopharmaceutical industry. In order to achieve this Government should consider:

Building technological capacity through critical inputs - In building technological capabilities in any sector, a key factor is the capacity to produce critical inputs and do so efficiently. In biotechnology Iran has begun this process by producing the critical reagents needed for research locally. Similarly, chemical inputs for the medicines need to be produced locally. Since Iran is presently investing in the petrochemical industry, it may produce some the inputs needed for the pharmaceutical industry.

Facilitating emergence of new firms - Presently, Iran has 55 pharmaceutical companies, less than one firm per million people. Each of these is producing a wide range of products for a variety of diseases. This situation discourages firms from specializing in some therapeutic areas and deepening their knowledge in those areas. Government should, therefore, promote the emergence of new pharmaceutical companies, with a focus on specific therapeutic areas from the inception. Stimulating innovation will require the introduction of a healthy competition among them.

Building critical mass in R&D - At the moment, the number of senior researchers (with PhDs) seems to be very limited in the field of medical biotechnology. Since the number of research projects is also small the shortage of personnel may not be obvious. But, for Iran to build a competitive biopharmaceutical industry, the country should increase the resources (human as well as financial) devoted to the field by several times to build a critical mass of research and development activities. Another option to quickly build up the critical mass would be to license a potential drug candidate from a firm abroad, before it has undergone clinical trials (since the drug is still in the development stage, it will be cheaper to license it), carry out the trials in Iran, develop the formulation, manufacture and market it in the entire Middle-East.

CHAPTER 1. CREATING AN INNOVATION SYSTEM

Iran has a relatively well-developed science and technology infrastructure among developing countries. It has also built up a significant industrial base, mainly by licensing technology from abroad. However, the export base is narrow and, in the long-term natural resources are exhaustible. It is, therefore, imperative to diversify the economy and further broaden the industrial and export base. In order to achieve this, Iran needs to create an innovation system that can not only import and adapt technologies, but also improve up on them, innovate new technologies and diffuse them economy wide.

Iran's efforts to transform from natural resource-based economy towards a knowledge-based economy are reflected in its science, technology and innovation policies. Iran is gearing up its national innovation system for this transformation by focusing on building up capabilities in high technology areas such as biotechnology, petrochemicals and new materials. Iran's strength lies in its human resources (well-trained scientists and engineers) and its natural resources (a large variety of flora, fauna and oil and gas). These resources if used effectively, can transform the economy in a reasonably short period of time.

1.1 Economic Setting

Since 1990, Iran's economic plans have emphasized a gradual move towards a market-oriented economy and development of private sector. In particular, the Fourth Five-Year Development Plan (TDP) committed the government to a program of liberalization, diversification and privatization. Subsequently, a number of reforms were approved, in particular:

- Approval of the Foreign Investment Promotion and Protection Act, aimed at simplifying the inflow of foreign capital and easing of technology transfer from abroad.[1]
- Liberalization of foreign trade through the elimination of non-tariff barriers and regulations for contract deposit.
- Equalization and reform of the system of exchange rates, aimed at increasing transparency in governmental budget and subsidies.
- Reform of the Direct Tax Law, consisting in the reduction of corporate taxes from 54 to 25 percent, and person income tax rates from 54 percent to 35 percent.
- Reform of the Banking System, through the establishment of non-banking credit institutions and private banks.

The reform process has been slow and there have been delays in implementation. Nevertheless, progress is reflected in the general improvement in macroeconomic

1 In May 2002, the Expediency Council approved the 'Law on the Attraction and Protection of Foreign Investment', which aims at encouraging inflow of foreign investment through streamlined procedures and profit repatriation guarantees. The Law was sent to Government for implementation in January 2003.

indicators. Iran's GDP per capita increased by 2.0 percent per annum in the last decade, while it was in a downward trend in the 1970s and 80s. In recent years, GDP grew by 6.3 percent in real terms in 2002, 4.8 percent in 2001, 5.7 percent in 2000 and 3.6 percent in 1999.

The downside of this reasonably high growth, are large budget deficits that are, at least partly, the result of large-scale subsidies (amounting to about USD 4.7 billion per year) provided by the State on consumer items such as foodstuffs and gasoline. The State also subsidizes the imported input costs incurred by the industry.

1.1.1 Human development

An impressive achievement of Iran has been in its social and human development. As shown in table 1.1, significant improvements have taken place in health and education standards. Due to the government's commitment to reducing poverty and improving basic living standards and education, the UNDP human development index values rose from less than 0.6 in 1980 to 0.719 in 2001, moving Iran from the group of countries considered to have low human development to join the ranks of those with medium human development.

Table 1.1 Human development indicators – historical trends

Year	**1960**	**1980**	**1988**	**1997**	**2001**
Adult literacy rate (%)	14.5	41.8	57.1	74.5	77.1
Life expectancy (years)	49.5	51.2	61.6	69.5	69.8
Real GDP per capita (US$, PPP)	1,985	4,976	3,715	5,222	6,000
Human development index trends	0.562	0.566	0.646	0.690	0.719

Source: UNDP, Human Development Report 2002

The data show that Iran has made real major strides in improving the adult literacy rate from 14.5 percent in 1960, to 57 percent in 1988, to 77.1 percent in 2001, while the youth literacy rate (age 15 to 24) grew from 86.3 percent in 1990 to 94.2 percent in 2001. Moreover, the gap between adult men and women is narrowing. Out of the total number of higher education students enrolled in the academic year 1999-2000 (1.4 million), 635,973 were women, which represented 45.27 percent, while in 1978 (before the Islamic Revolution) the figure was only 30.87 percent.

The Government's commitment to human development and poverty reduction through innovation and application of modern technologies is reflected in the activities of the Persian Gulf Biotechnology Research Centre (illustrated in Box 1). Similarly, other national biotechnology research centres are also working on curing the diseases prevalent in the native communities in Iran (see the Chapter on Biopharmaceutical sector).

Box 1.1 - Human Development through Innovation – The Case of Qeshm Island

Innovation activities in the Persian Gulf Biotechnology Research Center (PG BRC), Qeshm Island, demonstrate how the fruits of innovation can be brought to benefit a disadvantaged community. A small research facility under dynamic leadership has helped eradicate malaria from Qeshm Island and the southern provinces of Hormozgan, Kerman and Sistan Baluchestan. Controlling malaria in these areas had been particularly difficult due to climatic conditions, uncontrollable border crossings and resistance of mosquito to chemical pesticides.

The PG BRC helped in developing a slow toxin-release formulation of micro-biological insecticide over 9 years at the Iranian Research Organisation of Science and Technology's (IROST). This organic pesticide, patented internationally as MH-14, was successfully tested through a participatory process in Qeshm Island. Malaria eradication, a part of Millennium Development Goals, has been achieved through the application of modern biotechnology to benefit a poor community and serves as a good example of the impact of technology on poverty reduction.

In addition to the successful work on malaria, the scientists at PG BRC have created a variety of potential income generating schemes for the indigenous population, including:

- Project to produce macro-algae as a useful food supplement to correct malnutrition in children and transferred to local householders under the supervision of PGBRC.
- Sea-weed cultivation, mushroom growing from date palm waste.
- Aloe Vera cultivation and Aloe powder production.
- Fermented fish paste (mahyaweh), date canning, micro-algae and sea-weed growing.
- Cloning of orchid varieties and development of colored pearls.

Qeshm Island Free Area authorities have put the development of local communities and culture at the core of their strategies, starting with development of a strong business infrastructure. Concurrently major studies are underway on development of eco-tourism, petrochemicals, marine biotechnology, local handicrafts and traditional ship-building. It plans to create a world standard centre of educational excellence, a robust telecommunications network, large industrial estates, technology incubation centre and future technology park and a bridge to the mainland, less than 2 km away.

The Qeshm Free Area, free from burdensome regulations and a with strong leadership, is demonstrating the practical impacts of innovation on creating sustainable livelihoods.

1.1.2 Employment

Creating gainful employment for the population is one of the challenges faced by Iran. According to official figures, unemployment rate has reached 11 percent and is expected to rise further (World Bank, 2003). The population growth has slowed down from a rate of 2.7 during 1975-2001 to an estimated 1.4 during 2001-2015 (UNDP-HDR, 2003). However, the growth in labour supply is now at a high rate of 5 percent a year, mainly due to the 'demographic bulge' in the early 1980s.

Presently, the manufacturing sector employs almost 30 percent of the work force (table 1.2) although it makes a relatively small contribution to the national product. Public services (essentially government employees) and social services (with relatively low salaries) are the biggest employers, along with agriculture, mining, trade and transport. The automotive sector is important as a major source of private sector jobs, employing a half-million persons.

Table 1.2 Non-oil sector employment

Sector	Number of employed persons (thousands)		Avg. growth,% 1991 - 1996
	1991	1996	
Agriculture	3,205	3,357	0.9
Manufacturing	3,616	4,473	4.3
Services*	6,276	6,741	1.4
TOTAL	13,097	14,571	4.2

Source: Plan & Budget Organization, 1997 * Including unregistered jobs

The number of persons employed increased from 13 million in 1991 to 15.5 million in 1999 and from 16 million in 2001 to 16.5 million in 2002. But, the number of unemployed people has doubled from 1.5 to 3 million during the same period. About 800,000 new job seekers per year are estimated to enter the job market until 2010.

The job-stimulus bill of 2002 passed by the Iranian Parliament is yet to make a significant impact. According to the World Bank estimates, to maintain present unemployment level of 11 percent the Iranian GDP needs to grow at an average annual rate of 6.5 percent and to reduce the unemployment rate to around 10 percent by 2010, the GDP growth rate would have to rise to 8 percent per year. Therefore, in order to meet this challenge successfully, Iran needs to diversify its economy from its dependence on the oil and gas sector.

1.1.3 GDP and Export composition

Presently, the Iranian economy is dominated by the State and is largely dependent on the primary sector. In spite of the commitment to privatization, the State-owned enterprises continue to account for much of the industrial sector. As there are many public-private enterprise variations, it is difficult to assess the exact contribution of private sector *per se,* but its contribution to GDP value-added is estimated at under 15 percent. Private sector companies are mainly concentrated in food processing, textiles and carpets, light manufactures and automotive components.

Although, Iran has a substantial industrial sector, its economy is still largely dependent on primary sector. The agriculture sector accounts for over 19 percent of the GDP and the oil and gas sector accounts for more than 11 percent, together taking the primary sector's contribution as high as 30.5 percent of GDP (see table 1.3).
(Note: this is not true with the new statistics for 2003)

Table 1.3 Sectoral contribution to GDP (in percentage)

Sector	1991/92	1995/96	2000/2001	2003
Oil & gas	10.8	16.1	13.4	11.1
Agriculture	22.4	22.2	18.9	14.0
Industry	19.5	19.7	18.9	23.4
Services	47.3	42.1	45.4	52.6

Source: Central Bank of IR Iran and World Bank data

Historically, as national economies mature, the share of agriculture in GDP declines while that of manufacturing and services rises sharply. In comparison, as shown in table 1.4, the value added of agriculture as a percent of GDP in Iran is about three times that of other emerging economies such as Malaysia and the Republic of Korea. The service sector's contribution to Iran's GDP is on par the Republic of Korea and better than Malaysia. But, with the domination of the State over the economy, much of the service sector in Iran may be accounted for by the government employment and its services. The manufacturing sector lags considerably behind Malaysia and the Republic of Korea. Correspondingly, the manufactured exports as percentage of total merchandise exports is only about 7 percent and Iran is far behind the comparative countries in this aspect.

Table 1.4 Sectoral contribution to GDP - comparison of Iran, the Republic of Korea and Malaysia

	Value added as % of GDP, 2001			Manufacturing exports as % total merchandise exports, 2000	Foreign direct investment, USD in millions, 2003
	Agriculture	Industry	Services		
Iran	19	26	54	7	120
Korea	4	41	54	91	3,752
Malaysia	8	50	42	80	2,474

Source: World Development Report 2003 (World Bank), World Investment Report 2004 (UNCTAD)

By adopting the twin strategies of self-reliance and import-substitution, over the years, Iran has developed a broad industrial base, including automotive, telecommunicaions and consumer electronics manufacturing. However, its export-base is rather narrow, even though the value of total exports of goods and services (as percentage of GDP) has been growing since the early 1990s. Primary commodities (oil and gas sector) continue to account for almost the entire (85 per cent) merchandise exported. Manufactured products account for less than 10 percent of the total exports and exports of ‘high technology’ products are almost non-existent (0.6 per cent of total exports and 2 per cent of manufactured exports in 2000).

As it will be explained further in Chapter 4, the oil and gas industry iself is aging and requires substantial investments for major repairs and upgrading. It is presently operating below the pre-revolution levels of 5.5 million barrels per day. Moreover, and most importantly, the majority of the oil extracted is exported crude and only a small proportion is transformed locally into refined oil and higher value added petrochemical products or technology-intensive products. As a result, Iran has become a net importer of refined petrol, as the figures on net exports in table 1.5 show.

Table 1.5 Net export of main petroleum products (crude and refined)

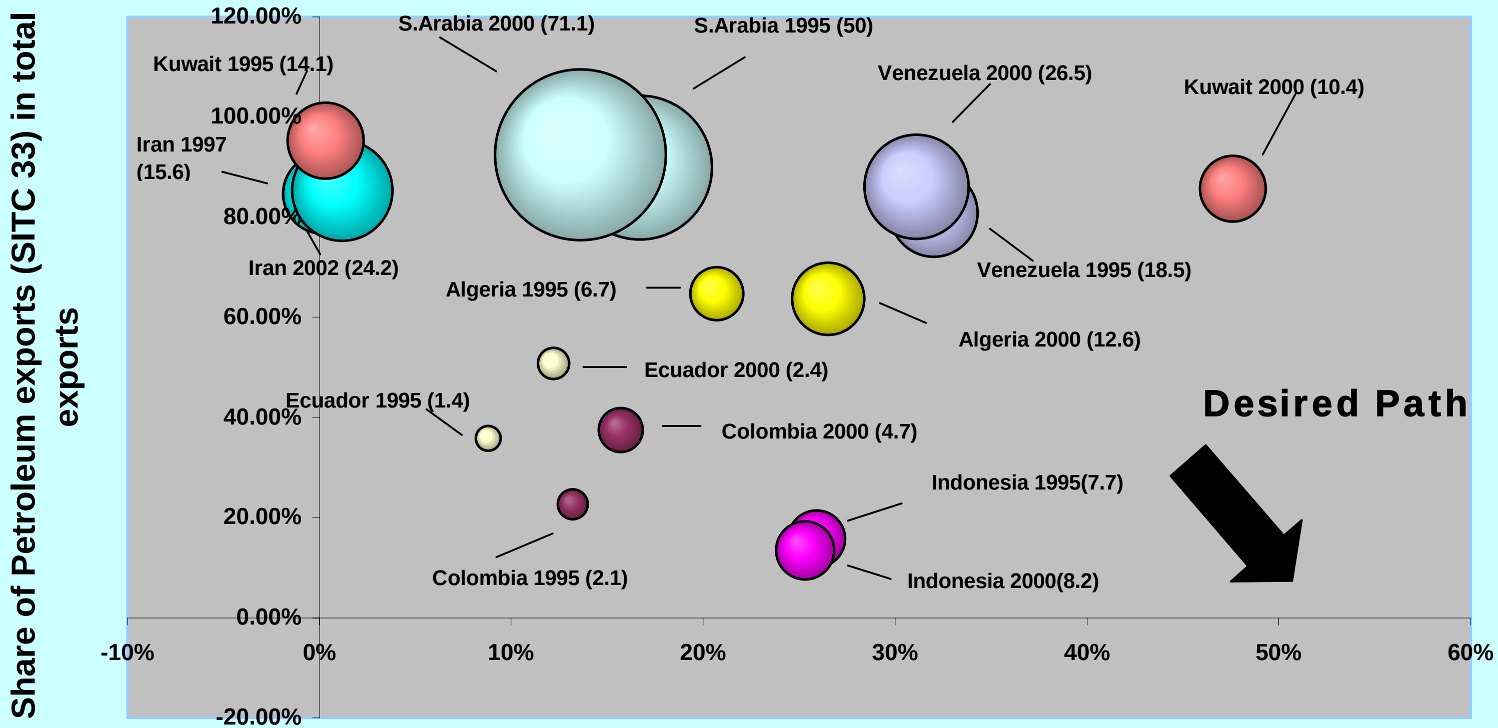
	Exports 2001 (US$ m)	**Net exports 2001 (US$ m)**	**Export growth 1997-2001 % p.a.**		**World trade growth 1997-2001 % p.a.**		**Share in world (%)**
Crude petroleum oils	18,997	18,997	13	..	14	1	5.9
Not crude oil	**175**	**-319**	**..**	**..**	**13**	**6**	**0.1**
Petroleum gases	426	424	23	12	16	3	0.5
Cyclic hydrocarbons	106	95	5	-8	13	7	1.1
Polymers of ethylene	21	-58	-10	-12	4	6	0.1

Source: ITC based on Comtrade data, 2002

Figure 1.1 shows that among oil producing countries, Iran is lagging behind others in producing/exporting value added petroleum products. During the last five years, Iran has not shown much progress in terms of moving along the value chain in oil sector exports, while other oil producing countries have progressed much faster. For insance, in 2002 the relation between the total share of refined and processed products in total petroleum exports on one hand, and petroleum exports in total exports on the other, was not so much different from that of five years earlier. The 'desired path' in the figure suggests that a country should diversify its export base, while at the same time increasing the value addition. Compared to other oil producing countries, Iran is moving very slowly along the value chain of petroleum production. On the other hand, countries such as Kuwait and Algeria have achieved remarkable progress along the desired path during between 1995 and 2000. One of the challenges faced by Iran's economy now is whether it can increase the proportion of refined and processed products in its total petroleum exports within a reasonable time period. This depends on the Iraian technological capacity and policies.

Among the non-oil exports, Iran’s main export products are carpets (3.5 per cent) and fresh and dry fruit (2.2 per cent). As shown by the ITC prospectus on Iranian export portfolio 1997-2001 (Figure 1.2), only the item “oil and other petroleum products” is located in the most dynamic section, 'champions'. Both carpets and dried fruit are located in the section characterized by adversity conditions (i.e. decreasing growth in the world trade for these products) and very limited increase for Iranian products in the world market share. Iran has a sizable industrial capacity and therefore, it has only one export product in the ‘champions’ segment.

Figure 1.1 Oil sector exports: moving along the value chain



N.B. Bubble size indicates the value of petroleum exports (US$ billion)

Share of refined and processed products (SITC 334-335) in total petroleum exports (SITC 33)

The challenge to Iran is whether it can quickly add more products to the 'champions' segement. Iran can atempt to increase the value of refined product exports. Given the Iranina capacities it can also add more products such as biotechnology, pharmaceuticals and petrochemical products to this segment within a reasonable time frame (see Chapters 3 and 4). Some of the agricultural products such as grapes, safron and fresh fruit are shown by the figure as having some dynamism. Iran can quickly add these products to the champions segment, by further processing these agricultural products and exporting processed products.

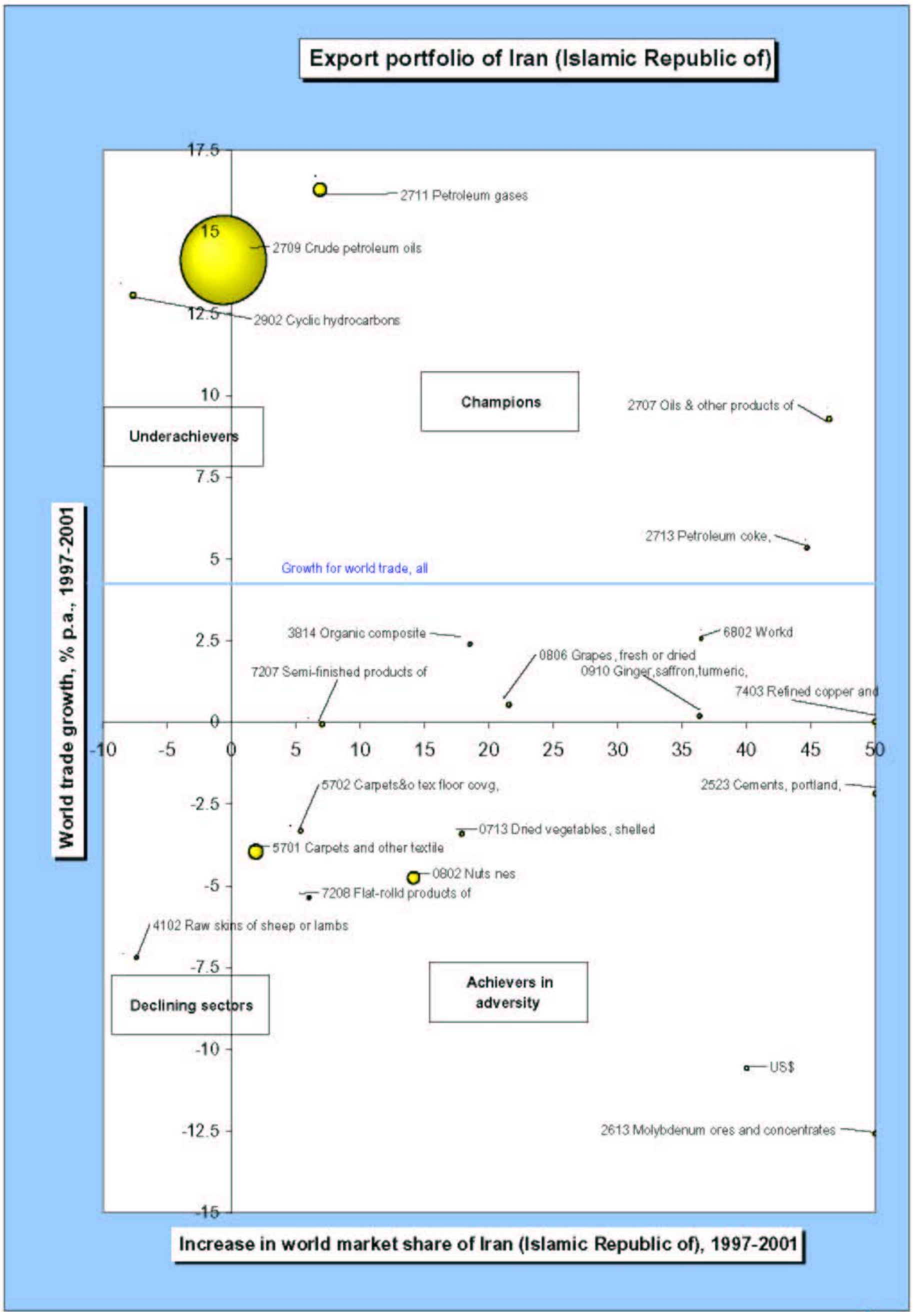
1.2 Technological Capacity

Iran has built up substantial technological capacity in terms research institutes/universities, scientists and engineers and production capability. According to one index, the 'Technology Achievement Index (TAI)', developed by UNDP, Iran is ranked 50 out of 72 countries that were assessed in 2001. The TAI is one of the most recent sets of indicators developed to assess technological capacity of a country: 'how well a country is creating and diffusing technology and building a human skills base'.[2] The countries that rank highest on the TAI are described as technological *leaders*. This group includes Finland, US, Sweden and Japan, along with two emerging economies the Republic of Korea and Singapore. The second level of *potential leaders* in technology includes a larger number of developing countries: Malaysia, Mexico, Argentina, Costa Rica and Chile. The third level, *dynamic adopters,* includes: Iran, South Africa, Panama, Brazil, China, Egypt, Indonesia, Sri Lanka, India and others.

Iran is ranked higher than some of the main *dynamic adopters* (e.g. India and Egypt), but after China, Brazil, Malaysia, South Africa and Mexico. The data in Table 1.6 show that Iran has a relatively high expenditure on education as a proportion of total government expenditure (20.4%) and a fair ratio of science enrolment in tertiary education, compared to several other developing countries (6.5). However, Iran has a very low proportion of technology-based exports (2% of the total goods exported). Comparatively, even Egypt and India that are ranked below Iran have a much higher proportion of technology-based exports (7% and 11% respectively). Iran's expenditure on R&D activities as a proportion of GNP is only 0.5 percent. In order to transform its economy into a technology-based one, Iran needs to increase its R&D expenditure substantially. In this respect Iran is lagging behind several other emerging economies such as Brazil (0.8%), India (1.2%) and South Africa (0.7%). Although, the tertiary science enrolment ratio of 6.5 in Iran compares favourably with other developing countries, the experience of countries such as the Republic of Korea and Singapore suggests that to transform into a knowledge-based economy, this ratio needs to be raised substantially.

[2] The "Technology Achievement Index" (TAI) is a composite of four dimensions – the creation and use of new knowledge (with indicators for patents granted and license fees received per capita), diffusion of recent innovations (Internet hosts per capita and tech-based exports as share of all exports), diffusion of old technology (log of telephones and electricity consumption per capita) and human skills (mean years of schooling and enrolment at technical tertiary levels). The TAI also provides indicators to measure potential direct and indirect inputs into an innovation process such as the share of educational expenditures in total government expenditures, the number of scientists engaged in research and development per million population and the share of R&D expenditures in GNP.

Figure 1.2



Note: the area of the circles corresponds to the export value of the product group for Iran (Islamic Republic of). See explanatory sheet for ...
Source: ITC calculations based on COMTRADE statistics.

1.2.1 University education and research

The number of research institutions has grown dramatically since the Islamic Revolution. The first research institute was established in Tehran in 1920. There were five research centers in 1951 and 57 in 1971. By 1982 this had risen to 86, ten years

Table 1.6 Knowledge and Innovation Related Indicators – Selected Countries, 2001

	Education, Expendit. % govt. exp 1998-2000	Internet Users/ 1,000 2001	Tertiary science enrolment ratio 1995 - 1997	R&D Expendit. % GNP 1996-2000	Tech exports, % goods exp 1999	Royalty Receipts $/person 2001	Patents to Residents per mill 1999	TAI Rank UNDP 2001
Argentina	11.8	100.8	12.0	0.4	15	0.6	4	34
Brazil	12.9	46.6	3.4	0.8	18	0.6	3	43
China	-	25.7	3.2	1.0	21	0.1	2	45
Egypt	-	9.3	2.9	0.2	7	0.7	1	57
IR Iran	**20.4**	**15.6**	**6.5**	**(0.5)**	**2**	**-**	**2**	**50**
India	12.7	6.8	1.7	1.2	11	0.1	1	63
Korea	17.4	521.1	23.2	2.7	39	14.6	931	5
Malaysia	26.7	273.1	3.3	0.4	67	0.9	-	30
México	22.6	36.2	5.0	0.4	33	0.4	1	32
Poland	11.4	98.4	6.6	0.7	12	1.2	26	29
Singapore	23.6	411.5	24.2	1.9	71	-	12	10
S. Africa	25.8	64.9	3.4	0.7	n/a	1.2	-	39
Germany	9.7	373.6	14.4	2.5	26	38.3	229	11
Japan	9.3	384.2	10.0	3.0	38	82.4	1,057	4
USA	-	501.5	13.9	2.7	44	135.5	298	2

Sources: World Bank, World Development Indicators and World Development Report, 1998/99, and UNDP, Human Development Report, Development Goals 2003, Technology 2001

later there were 191 and by 2001 there were 216 public sector research Institutes operating in Iran. Of these, 112 are affiliated with the MSRT. IROST, for example, was founded in 1980 and subordinated initially to the Revolutionary Council. Later it was affiliated with the Ministry of Culture and Higher Education and now with the MSRT. The National Research Centre for Genetic Engineering and Biotechnology (NRCGEB) established in 1989 is similarly under the supervision of the MSRT.[3] The first private research center was established in the 1970s and the MSRT's Report on Private Sector Research Institutes (Abassi et al.: 2003) notes that there were 76 technical and engineering research institutes in the private sector in 2000.

In 2000-2001, the private sector accounted for 52.8 percent of all enrolments in university degree programmes as compared with 47.2 percent for the public sector, but the latter is stronger academically and accounts for nearly all students enrolled in Ph.D. programmes. One quarter of all university enrolments are in engineering and a further 10 percent in pure sciences. Medical sciences account for an additional 9.3 percent of the students enrolled at the tertiary level.

Table 1.7 shows that the total number of graduates in sciences increased by three-times in a decade between 1991-92 and 2000-01. The total number of graduates in engineering also increased significantly from 5649 in 1991-92 to 13838 in 2000-01. In spite of such great strides in higher education achieved by Iran, the numbers are still

[3] In research in the field of biotechnology, MSRT thus plays an important role though there are other major research centres, such as the Pasteur Institute of Iran which falls under the MOH and Razi Vaccine and Serum Production Research Institute which comes under the Ministry of Agriculture (MOA). See Chapter 4 for further details.

Table 1.7 Number of university graduates in sciences and engineering (annually)

Sciences					Engineering			
Year	B.Sc	M.Sc	Ph.D	Total	BE	ME	Ph.D	Total
1991-92	4204	452	11	4667	5106	541	2	5649
1996-97	7332	861	37	8230	8075	1469	39	9583
1999-2000	10763	1058	128	11949	10497	1914	65	12476
2000-2001	12516	1300	143	13959	11467	2241	130	13838

Source: Institute for Research and Planning in Higher Education (2002)

low in relation to the size of population of Iran (55 million). This is particularly true in the case of post-graduate degrees. With over 70 institutes of higher learning in public and private sectors, the number Master's degree graduates in all sciences together is only 1300. The proportion of students going for further education is small.

The number of scientists graduating annually registered an increase: from 340 per one million population in 1996, to 560 in 2001. However, this number may not be adequate to propel the economy into higher levels. The number of scientists per million population is still much lower compared to other emerging economies such as the Republic of Korea or Taiwan Province of China that have successfully transformed their economies. The number of scientists and engineers will have to be increased considerably.

Presently, these human resources have provided a strong base for research and technological development. There has been a significant increase in the number of 'scientific articles' published in international journals from 281 in 1992 to 1872 in 2002. This indicates considerable strengths in scientific research in Iran. However, with over 60 universities and several research institutes in public and private sectors, the number of publications per year is still far below the potential.

During the 1990s, the Ministry of Industry also sought to directly promote research and development activities in large and medium-sized companies, most of which were state-owned. By 1996, 158 companies had received official operating licenses for their R&D centres (MSRT, Vice Ministry for Technology: Aug. 2003,15). The MSRT's Report on "Private Sector Research Institutes (2003) notes that 76 technical and engineering research institutes had been created in the private sector by 2000. The earliest was established in 1971 followed by three others in the 1970s, 17 in the 1980s, 52 in the 1990s and two in the year 2000.

Of relevance to the role of research in industrial innovation, however, is the relatively small proportion of researchers located in private research centres. In 1996 the total number of researchers, research assistants and technicians amounted to 68,385 persons of which 82 percent were employed in public sector institutes and 18 percent in private sector research centres. The number of researchers (including Ph.D. students) per million population increased from 340 in 1996 to 560 in 2001.[4] What is

[4] MSRT, Vice Ministry for Technology, Aug. 2003

not known is whether this growth has altered the distribution of researchers across private and public sector institutes.

1.2.2 Technology infrastructure

Today, both Internet access has a major bearing on overall technological capacity. Telecommunications infrastructure and the Internet in particular, are considered to be a prime requisite for access to knowledge, for learning and for the kind of networking that leads to competitiveness. With regard to 'telecommunications infrastructure', Iran has done extremely well in connecting people via telephone mainlines, but in the number of Internet users, it is well behind other oil producing countries (see Table 1.8). Greater attention will be needed in the future to widening Internet access.

Table 1.8 Telecom Diffusion - Iran in comparison with other oil producing countries

	Telephone mainlines (per 1,000 people)		**Cellular subscribers** (per 1,000 people)		**Internet users** (per 1,000 people)	
	1990	**2001**	**1990**	**2001**	**1990**	**2001**
Egypt	30	104	0	43	..	9.3
Kuwait	188	208	12	386	..	87.9
Indonesia	6	111	0	242	0.1	64.9
Islamic Republic of Iran	**40**	**169**	**0**	**32**	**..**	**15.6**
Mexico	65	137	1	217	0.1	36.2
Saudi Arabia	77	145	1	113	..	13.4
Syria	41	103	0	12	0	3.6
Venezuela	76	109	0	263	0.1	46.8

Source: UNDP, Human Development Report 2003

The government is making efforts to improve the technology infrastructure. The Supreme National Council for the *Information & Communications Technology Agenda (TAKFA),* under the leadership of the President's Special Envoy, has recently initiated some 40 national projects in the fields of ICT infrastructure, commerce, governance, human resource development, and employment. With high priority given to the knowledge economy in the Fourth Plan, and a budget of USD 1,000 million allocated for intensive ICT work, Iran can be expected to make significant progress in converting the digital divide into digital dividends.

1.2.3 Technological capacity in the industrial sector

Two specific policies introduced during the period of reconstruction have attempted to reorient research more towards industry. The first was to promote applied research with a view to making university research applicable to industrial needs. During the 1990s, the Ministry of Industry also sought to directly promote research and development activities in large and medium-sized companies, most of which were state-owned. By 1996, 158 companies had received official operating licenses for their R&D centres (MSRT, Vice Ministry for Technology: Aug. 2003). The MSRT's Report on "Private Sector Research Institutes (2003) notes that 76 technical and engineering research institutes had been created in the enterprise sector (including public and private enterprises) by 2000. The earliest was established in 1971 followed by three others in the 1970s, 17 in the 1980s, 52 in the 1990s and two in the year 2000.

Of relevance to the role of research in industrial innovation is the relatively small proportion of researchers located in private research centres. In 1996, the total number of researchers, research assistants and technicians amounted to 68,385 persons of which 82 percent were employed in public sector institutes and 18 percent in private sector research centres.

Apart from building up capacities in the knowledge system, Iran has also built up substantial technological capacity in the productive sector. It has a fairly well developed manufacturing capacity in industries such as automotive, telecommunications and pharmaceuticals. But, the knowledge system did not percolate into the production system properly. The enterprises only undertake production, but do not perform innovation activities. While such a strategy was sufficient to cater to an import-substitution economy, it is not a dynamic capability for sustainable development. Moreover, even large manufacturing enterprises rely on imports for inputs. This is mainly because of the absence of strong support industry (supplier networks in the form of small and medium enterprises) in Iran. The small and medium enterprises make relatively very small contribution to the national product.

Large enterprises (which are mainly State-owned), by innovating technologies relating to components and parts and diffusing these technologies to SMEs can build up a strong supplier industry within the country. Several other developing countries such as India and China have followed such a strategy. SMEs create employment and are dynamic, adapting to economic changes relatively quickly. SMEs are also observed to be more innovative than large enterprises.

Unfortunately, Iranian statistics relating to SMEs are scattered and incomplete. The Guilds Board and Ministry of Commerce cover service and trading businesses that employ around one million persons. The Agricultural Jihad Ministry is responsible for small agro-based and rural industries. Registered with the Ministry of Industry are about 345,000 small/medium industrial enterprises that employ 1.6 million or about 10 per cent of the total employed work force. The employment and production situation of enterprises licensed by the Ministry on Industries (March 2002) is summarized below.

Table 1.9 SMEs registered with the Ministry of Industry, 2002

Enterprise size	**Micro** **1- 5 employees**	**Small** **6 – 50 employees**	**Medium** **50 - 150 employees**
Number of enterprises	17,376	90,452	2,704
Employment	68,328	541,997	207,961

Source: Ministry of Industry and Mines

The state-sponsored service providers include the Vocational Training Organization, Industrial Management Institute, Industrial Estates Corporation, as well as Science & Industry Service Companies run by provincial universities. However, vigorous private-sector business services for consulting, training, information and technology assistance are yet to emerge.

The rationale for promoting small and medium scale enterprises in Iran is not one of scale but rather of scope: they usually cover a heterogeneity of products and services, based on a variety of skills, materials and markets, and create a range of benefits for the local and national economies.

In Iran small businesses suffer from similar obstacles as in other developing countries. These include: the poor macro-economic environment of high inflation (about 20 per cent, with a fluctuation of 9-10 per cent) and interest rates; burdensome regulations; adverse labour and tax laws; lengthy and arbitrary procedures of securing bank loans; foreign currency shortages; lack of competent business development services; and an overall sense of discrimination against small enterprises. This situation is made worse by the dominance of the oil sector in the overall economy, and of large state enterprises in industrial production. Thus, the potential for sub-contracting to SMEs by the large automotive, transport, home appliances and oil industry is yet to be realized.

In summing up, the Iran’s technological capacity should go beyond its dependence on transfer of technology from abroad and develop the capability to innovate and diffuse new technologies. Therefore, Iran needs to create a dynamic and effective innovation system.

1.3 The National System of Innovation

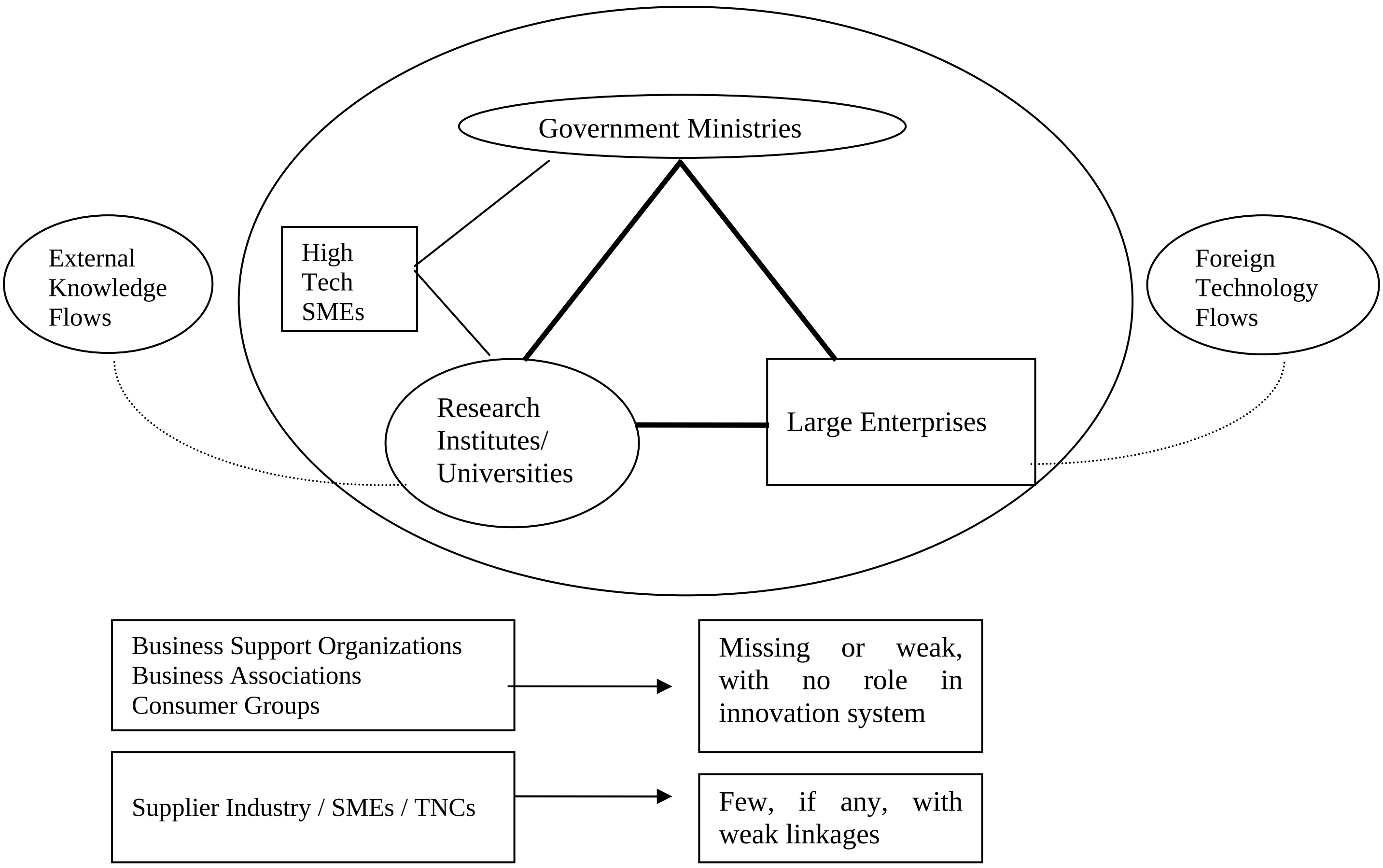
Countries that have successfully transformed their economies to compete in technology- and knowledge-intensive sectors have done so by creating and strengthening their national system of innovation (NSI). An innovation system is a network of economic agents whose activities and interactions bring new products, new processes and new forms of organization into economic use. The key agents in this network include, enterprises, the universities and research institutes, the government, and other support institutions such as industry associations, consumer groups, business support organizations and financial institutions. Continuous interaction between these actors and the learning opportunities created as the result is critical for innovation. Innovation here does not mean something entirely new to the world, but new to the given firm or country, the ability to understand, master the new technology and adapt it and apply to the specific national or sectoral context.

1.3.1 Salient features of Iran's innovation system

As shown in Figure 1.3, the major actors in Iran's national system of innovation are government ministries, research institutes/universities and large enterprise. By virtue of ownership of almost all the research institutes/universities and a vast majority of the enterprises, the government has become the most significant player in Iran's NSI. With the exception of a small number of high-tech start-up enterprises, the contribution of the private sector to innovation and technology development is limited. Government-owned research institutes and universities perform most of the innovation/technology development activities.

Figure 1.3 graphically represents the main actors in the Iranian innovation system. It shows that some elements and interactions in the innovation system are fairly well developed, whereas others are weak, while some important ones are missing. At its core are the strong interactions between government ministries on the one hand, and research institutes/universities and large enterprises on the other. The nature of this interaction ranges from prioritization of research areas by the relevant ministries to the funding of specific research projects. The research institutes/universities, in turn, monitor technological developments and provide feedback to the ministries to facilitate decisions relating to research priorities. The Technology Cooperation Office (TCO) under the Presidency is also an important actor in the innovation system and has strong links with the research institutes, established mainly through funding of research projects that can be commercialized by Iranian enterprises. The link between research institutes/universities and large enterprises is also strong. Many large enterprises in Iran do not have in-house R&D capacity and they tend to rely on research institutes for product development and process innovation. Links have also been observed between high-tech SMEs on the one hand and research institutes/universities and government ministries on the other.

Figure 1.3 National System of Innovation in Iran



Many of the research institutes/universities in Iran have built up impressive capabilities ranging from basic research to product and process development. They also have strong ties to industry and the government through sectoral ministries. Unfortunately, interactions among them are somewhat weaker and in many cases non-existence. Coordination of objectives and activities among the different institutions is rather weak. However, a solution to this problem is being sought. The government intends to establish research councils and coordination committees to prioritize research programs and allocate tasks between different institutions. For instance, in the biotechnology sector, the different research institutes/universities, which are under different ministries such as MSRT, MOH and MOA, already collaborate in providing postgraduate education.

Innovation activity in Iran is supply driven in the sense that the government basically sets research and development programs and projects to be undertaken by research institutes/universities. As the result, decisions on R&D priorities tend to be based on perceived immediate economic or social needs rather than research programs based on consumer demand or long-term strategy. Moreover, due to the weak R&D capabilities of the enterprises, the research institutes/universities are also compelled to carry out even down-stream activities of R&D such as product and process development and testing. As a result, research projects take a long time to complete.

What are the key elements that are currently missing or weak in the Iranian innovation system?

- Lack of continuous interaction with international research institutes and other knowledge-based institutions. In general, the level of contacts or collaborative projects between Iranian R&D institutes and universities and similar institutions located in developed countries, where much of the technological developments take place, is limited. The context for knowledge acquisition today extends well beyond national frontiers and domestic policies should actively encourage national actors to acquire technology and know-how from abroad.

- Limited R&D and innovative capacity at the enterprise level. In more developed innovation systems, the enterprise sector plays a central role as a driver of the innovation process in interaction with suppliers, consumers, research institutes/universities and supporting institutions. In Iran, only a limited number of large enterprises have their own in-house R&D capabilities. The role of enterprises is largely that of 'manufacturers of products'. For product development and R&D related activities, both large enterprises as well as the high-tech SMEs, rely on research institutes/universities. In the pharmaceutical sector, for example, even the large enterprises (public as well as privatized ones) depend on the research institutes for the development of processes to manufacture generic drugs.[5] This is a major limitation, as enterprises need an in-house capacity to engage in a process of continuous innovation and in order to successfully transfer technology from abroad. As a

[5] Another unique feature of the pharmaceutical sector is the manufacturing activities of the research institutes. These are integrated organizations combining research, education and commercial production of drugs (e. g. Razi Institute and Pasteur Institute).

result, the direct contribution of large enterprises to innovation/technology development activities is limited.

- The role of foreign investment in the Iranian innovation system is at present insignificant. Globally, transnational corporations (TNCs) play a profound role in shaping the structure of markets and the pace and direction of technological change. Their presence in a host country provides an opportunity for learning, transfer of skills and knowledge through supplier networks and spillover effects. But, TNCs play only a marginal role in the Iranian economy and, therefore, they contribute very little to the development of the national innovation system.

- Weak supplier network. Iran has significant production capabilities in several industries such as automotive, telecommunications and pharmaceuticals. However, even large manufacturing enterprises rely on imports for inputs. For instance, pharmaceutical industry imports more than 70 percent of its inputs. This is mainly because of the absence of strong support industry (supplier networks) in Iran. Globally, in mature industries, such as automotive and pharmaceuticals, interactions with suppliers are important drivers of innovations. In Iran, because of its weakness or absence, the support industry makes no contribution to the innovation/technology development activities. Supporting the development of SMEs will strengthened greatly the supplier network in Iran.

- Lack of competent and well-financed technology support infrastructure. Enterprises or institutes do not innovate in isolation. In addition to interactions with customers and suppliers, continuous and appropriate support from specialized technology-related institutions is essential. Iran has made some progress in building some of support structure for innovation but more needs to be done. In recent years, the idea of establishing science parks and incubators has gained momentum with both national and regional governments. MSRT first established the Isfahan Science and Technology Town and following its successful experience, MSRT decided to establish new science parks in different provinces by converting the existing branches of IROST in those provinces. The MIM also took upon the idea and established a couple of technology parks. These science and technology parks are geographically located close to universities/research institutes. Start-up enterprises set up by the students and researchers from these universities are the main tenants in these science parks. As a result, science parks have strong ties to the universities/research institutes. MSRT, MIM, MCIT and TCO provide research loans and grants to some of the enterprises located in these science parks. Governors and provincial officials are making efforts to mobilize financial resources and obtain necessary approvals for developing science parks in their respective provinces. However, the scarcity of financial resources, the lack of expertise and experience in developing and managing science parks along with all the technical and business support services are hindering the process.

- Absence of active business and consumer-based organizations. Within the Iranian NSI, the role of business support organizations (technical, financial and commercial support) and business associations is marginal. The consumer groups play even lesser role in influencing the innovation/technology development activities. Even the research institutes/universities, which are the principal sources of innovation, have no links with the consumer groups. This is a clear indicator of the fact that innovation activities in Iran are not driven by "demand" but by the governmental plans.

1.4 Assessment

Although Iran is richly endowed with both natural resources and well educated scientists and engineers, this potential advantage has not yet been capitalized for achieving the transition from an oil-driven to innovation-driven growth due to the weaknesses in the national innovation system. The Iranian case shows that ready or simple access to technology does not automatically mean that the technologies obtained through transfer arrangements are effectively diffused and adapted to local conditions, resulting in dependence on endogenous technological capacity.

Increased oil revenues in the early 1960s and 1970s helped to mitigate the technological constraint on growth by making foreign technologies more easily accessible. Iran adopted an import substitution industrialization policy and used its oil income to buy foreign technologies. Ready access to technology did not, however, mean that technologies obtained through transfer arrangements were, *ipso facto*, effectively utilized and/or improved upon, nor that a diversified export capacity in downstream value-adding industries such as petrochemicals was automatically created.

By more efficiently managing its oil wealth and by re-deploying the significant oil-revenues to growth and away form energy subsidies (now over 10 per cent of GDP), Iran would have the resources needed to expand the non-oil based economy, building downstream petrochemical and other value-adding industries, as well as stimulating innovation into new products and processes and creating links to forward linking users (autos, textiles, new materials for other industries).

Furthermore, by promoting the creation of local enterprises, which are flexible in responding to demands from potential users and by adopting incentives for them to innovate, Iran could develop a competitive productive capacity in both capital and consumer goods for its large domestic market and become an export base for manufactured goods to the Middle East and Western Asia. Movement in this direction would help reduce unemployment, and in general contribute to poverty alleviation and the development of local communities in the most remote areas on the country.

Iran’s political leaders have clearly set as their goals for the next five years to boost research and technology and strengthen in-house research in the productive sector, create quality jobs and make the economy less dependent on oil. A new set of policy measures and related resources, building upon those adopted under the Third Development Plan, are expected to be put in place. These would emphasize the adoption of policies to enhance innovation, develop internal and external sources of R&D as well as the transfer mechanisms needed to strengthen technological capacity in the country. In this context, some areas require closer attention.

- The contribution of the enterprise sector to innovation activities is weak and should be strengthened. Enterprises are mainly production units rather than technology developers. All innovation activities are concentrated in the research institutes and universities. The Government has started encouraging enterprises to set up R&D units. But, the effect so far has been limited in terms of actual innovation activities at the enterprise-level.

- At present, competition between enterprises, which is a major driver of innovation, is lacking in several sectors and where it exists, it is limited to competition based on price. The kind of competition that drives enterprises to innovate is completely missing.

- The role of FDI in the Iranian innovation system is at present marginal. The Government should develop a strategy to attract and benefit from foreign direct investment (FDI). Given its natural resources (including a variety of flora and fauna) and the large domestic market, Iran is well placed to attract FDI. The approval of the foreign investment promotion bill in May 2002 is yet to make any significant impact in terms of FDI inflows, although during the first 5 months of 2004, approved investment projects account for more than $4 billion. The approval of an investment promotion bill in March 2001 accounted for about $2.4 billion in investment projects during 2002-2003, more than 50 percent of the total foreign investment during 1993-2003. FDI not only brings in new technologies in the form of new products, processes and managerial techniques, but also spurs competition in the economy. Transnational corporations are one of the key players in the national innovation systems worldwide. Presently, these key players are absent in the Iranian innovation system.

- The Government of Iran should give a ‘big push’ to the development of small and medium enterprises (SMEs), one of the weakest links in the innovation system. SME development should not be confined to high tech sectors alone. Development of SMEs in the traditional sectors can create a vibrant supplier network to the large enterprises (which is completely lacking at present) and strengthen the linkages between various actors in the innovation system.

- Development of innovative SMEs requires dynamic entrepreneurs. Presently, entrepreneurship is weak in Iran. This is partly explained by the lack of opportunities, financial and technical support services and clarity with respect to ownership of private property as well as a weak intellectual property rights regime. Government should address these problems and promote and encourage entrepreneurship. The present system of bank loans for innovation activities by scientist turned entrepreneur based on certification by the research council is a crude way of providing financial support. Instead, Government should form specialized agencies to provide seed capital and encourage banks to develop ‘venture capital’ activities. Such financing mechanisms will promote entrepreneurship by reducing the risks to individuals and thus, result in greater commercialization of innovations.

CHAPTER 2. THE POLICY FRAMEWORK

Iran's innovation policy is entrusted to the Ministry of Science, Research and Technology (MSRT). However, a number of other institutions are also directly involved in the innovation policy process, among which are the Ministry of Industry and Mines (MIM), Ministry of Communication and Information Technology (MCIT), Ministry of Jihad – Agriculture (MJA), Ministry of Health, Treatment & Medical Higher Education (MOH) and the Ministry of Petroleum (MOP). Their role in the policy-making and implementation process is examined in this chapter.

Not all countries have Ministries of Science and Technology. Among the many that do, however, functions differ substantially both across countries and within countries overtime. Three broad conceptual approaches characterize the focus and objectives of these Ministries and the functions and policy instruments that are assigned to them:

Promote scientific research - In some cases, Ministries of Science and Technology have emerged out of Ministries of Higher Education and were shaped by an interest in promoting research. The MSRT in Iran similarly traces its roots to higher education and the scientific research associated with it.[6]

Technology development - In others cases, the explicit focus lies more in the need to organize and expand publicly funded research and orient it towards technology development. for example, before the creation of a Ministry of Science and Technology in Brazil, a National Council for Science and Technology had been created in 1951 with the objective of providing grants for research to universities and public sector research institutes. There are echoes of the Brazilian approach in the attachment of IROST, the Iranian Research Organization for Science and Technology, to the new MSRT, enlarging its functions beyond the higher education and scientific research components that were at the core of its earlier activities, to include technology development.

Link research to industry - In still other cases, the objective has been to encourage public sector research bodies to link more closely to industry. For example, efforts have been made in France to: transfer knowledge through an exchange of personnel; locate universities and enterprises in science and technology parks (Technopoles) as a means to stimulate the development of collaborative technology development projects between them; commercialize technology through licenses; and policies and programmes designed to encourage scientists to become entrepreneurs.

The experience of other countries suggests that there is no single way to efficiently manage the relationships between education, research, technology development and production. Even when strategic goals and objectives are clear, there are tremendous difficulties in determining what the focus and functions of the various actors in the policy process or the division of labor between them should be. The question of which

[6] Prior to the Islamic Revolution in 1979 'higher education' formed part of the Ministry of Science, where 'science', *olum* in Farsi, was the plural form of 'knowledge'. Knowledge generated through higher education and scientific research were thus the core functions of this Ministry.

national institution or ministry should have the leading role in a national innovation system is also not easy to answer. Frequently, in developing countries, this role is assigned to the Ministry of Science and Technology. But it is not easy for a single ministry to serve as the national coordinating body for innovation policy across producing sectors or to play a role in overcoming a problem common to many developing countries, the very weak demand for new technologies coming from the enterprise sector.

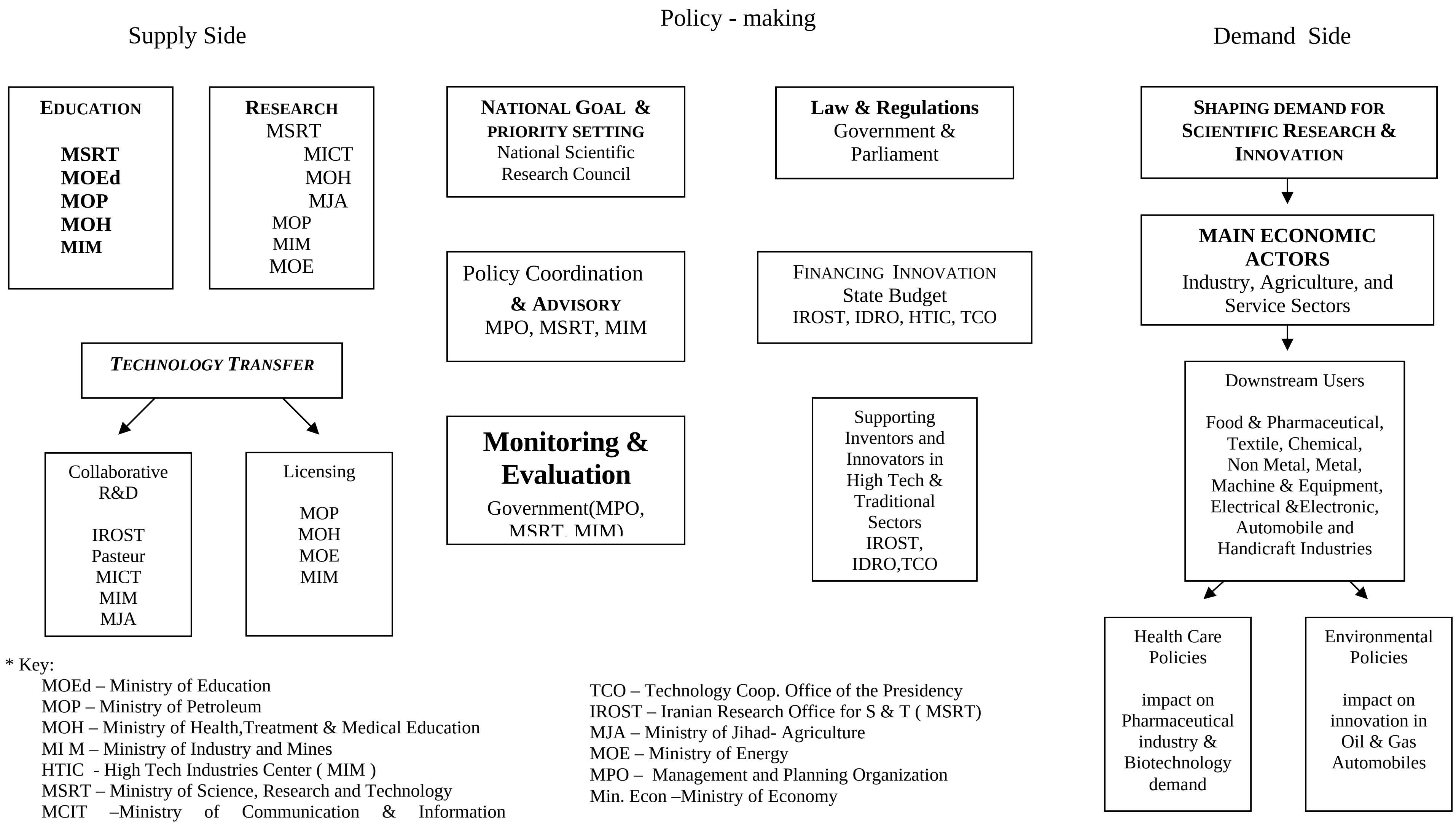
2.1 The Iranian Policy Framework

The Third Five Year Social, Cultural and Economic Development Plan (2000-2004), sought to promote the development of a knowledge society in Iran by strengthening the role of science and technology in the innovation process. This is further re-stated in the Fourth Five Year Plan. Accordingly, Government, building upon its earlier knowledge base in tertiary education and scientific research, added the function of technology to the renamed Ministry of Science, Research and Technology (MSRT). This new Ministry was designated the coordinator for science and technology policy-making for innovation across a large number of vertically integrated Ministries operating in the productive sector but maintaining few horizontal linkages among themselves. The ratification by the Parliament and the Council of Guardians of the Bill on Objectives, Missions and Structure of the MSRT on the 8th August 2004 will enable MSRT to play its coordinator role more effectively.

Over the years, the number of players with a direct role in science, technology and innovation policy-making has continued to expand (Figure 2.1). In the process, functions have tended to overlap and principal agencies lay claim to broad mandates that has made coordination difficult. Overall goal and priority setting remain weak with respect to science, technology and innovation policy coordination, monitoring & evaluation, financing technological upgrading in traditional sector enterprises and policies aimed specifically at shaping the demand for scientific research and innovation through demand pull strategies. With the ratification of the MSRT Bill in August 2004 and the establishment of The Supreme Council for Science, Research and Technology several of these problems can now be resolved.

In analyzing the current functions of the principal actors in the innovation policy making process, this chapter suggests that a tacit division of labor has, nonetheless, begun to emerge with respect to ‘high technology sectors’ in the economy and in programmes currently underway in the MICT and the MIM to support private enterprises and this needs to be made explicit. So, too, must channels be established for consensus building through which a national vision in science and technology and its role in innovation can emerge and national priorities set.

Figure 2.1. Distribution of Functions in Iran's Policy Framework*



Science and technology policies, moreover, are almost exclusively focused on ‘high technology sectors’ as drivers in the economy. This (as shown in Chapters 3 and 4) creates a disincentive to develop policies that stimulate linkages between these ‘high technology sectors’ and traditional industries and downstream productive activities. The truncated national system of innovation (described in Figure 3 of Chapter 1) that has emerged thus lacks both a strong domestic user-producer dynamic at its core and a strategy for building a culture of innovation within the society and economy more broadly.

2.2 The Ministry of Science, Research and Technology

The principal functions of the MSRT lie in the area of higher education and in scientific research and technology. Each of these functions falls under a Vice Minister who has responsibility for planning, goal setting and policy-making in these areas (MSRT: Vice Minister of Technology, Aug. 2003). The MSRT’s policy-making and planning responsibilities are carried out primarily with respect to public sector universities and research centers and the research institutes affiliated with this Ministry. The latter, fall under the Vice Ministry of Technology and include IROST in Tehran, the ten provincial Research Centers now transformed into the core of technology parks in their respective regions and the National Research Center for Genetic Engineering and Biotechnology (NRCGEB).

Box 2.1
Former Provincial Research Centres of IROST

Arak Research Center
Arak Industrial Information Center
Esfahan Research Center
Tabriz Research Center
Shahrood Research Center
Shiraz research Center
Kerman Research Center
Gilan Research Center
Mashad Research Center
Yazd Research Center

In addition to its traditional responsibilities, the MSRT was assigned a number of broader functions under the Third Five Year Plan. These included a role in proposing science and technology policies to the ‘Supreme Council for Science, Research and Technology’ and responsibility for the coordination of science and technology policy. Formation of the Supreme Council for Science, Research and Technology, however depends on ratification of the MSRT bill. It is expected that ratification of this bill will help in overcoming a legacy of weak horizontal linkages among ministries and enable the MSRT to carry out its coordinating function.

Goal-setting and policy-making

The MSRT's functions in goal-setting, planning, policy-making and finance differ considerably across the education, research and technology sectors[7]. The higher education area has by far the broadest set of such functions. It plays an important role in goal setting, policy-making, monitoring and evaluation. Policies and goals, for example, have been established with respect to the number of students/ year/ discipline/ university/ public or private; the programmes for the different levels: graduate, MSc. and Ph.D., projections for the number of students to be sent abroad; the research to be carried out at the universities and the corresponding capacity for its realization as well as the procedures for monitoring both public and private universities[8]. Some higher learning institutions, such as the Universities of Tehran and Shariff are considered to have achieved a high educational level in the field of science and technology and students graduating from these Universities easily find places in Ph.D. programmes at home and abroad. The number of patents obtained by universities in Iran, moreover, has increased by 600 per cent in the last three years. The higher education sector within the MSRT has a relatively comprehensive plan for the development of qualified personnel for the research sector and its implementation appears to have been successful.

Programme & Project Monitoring and Evaluation

With regard to research, the focus is explicitly on "academic research" and these activities are only weakly linked to the National S&T Plan and the broader National Social, Cultural and Economic Development Plan which appears to have been elaborated with little discussion and interaction between different Ministries and S&T organizations such as IROST (Interviews).

In contrast to its role in the education sector, less comprehensive planning for the expansion of research seems to be taking place within the MSRT. Similarly, the role played by the Vice Ministry for Education in setting standards, monitoring and evaluation in the education sector is not duplicated in the research sector. Monitoring of research projects is inadequate and the evaluation of research quality makes use of a scientometric approach based on the Science Citation Index.

Scientometric methods are widely employed in OECD countries as a measure of research quality but their scope is limited and the number of citations does not necessarily reflect the importance of the knowledge generated in a given country. Thus citation indices are useful mainly to assess the results of basic research that fall within the worldwide mainstream of knowledge, but, are not appropriate as a tool for evaluating applied research or research results that have a national or local impact and consequently are of national importance[9]. Basing evaluations of research quality and impact mainly on scientometrics is thus not only insufficient but it creates a major

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[7] Information in this section comes from the MSRT, Vice Ministry for Technology: August, 2003 and interviews.

[8] Based on information from a document entitled Policies and Initiatives in the Islamic Republic of Iran mentioned on-line at: http://www.mche.or.ir/English/Policies.htm.

[9] The range of publications included in such indices, moreover, are biased against publications in developing countries and in foreign languages thus further excluding publications that have local utility and impact. .

disincentive for researchers to link to industry where projects are less likely to produce the kind of theoretical publications that invite citations.

The Research Support and Logistic Department, within the office of the Vice Minister of Research is responsible for preparing the proposal to government dealing with the distribution of R&D funding among Ministries. Approximately 96 per cent of the research budget comes from the State and 4 per cent from enterprises. About 0.6 percent of the GDP is spent on R&D, and of this some 7-8 per cent is dedicated to basic research. The R&D budget is roughly distributed as follows: universities under the MSRT receive approximately 20 per cent of these research funds, 10 per cent goes to Medical universities and 40 per cent to the agricultural sector. The remaining 30 per cent of the R&D budget is distributed among other sectors.

The Department also helps research institutes from other Ministries to secure additional funding for their work. First, a peer evaluation of the request is made on the basis of the respective ministry's priorities, and, if positive, the Department negotiates with an Iranian bank to obtain a loan for the institute at low interest rates. The Government pays part of the interest rate as a subsidy. The Department is also studying the creation of an insurance system in the area of S&T to protect institutes that cannot repay their loans or keep up interest payments.

Despite the attention paid to standard setting, monitoring and evaluation in the education sector, little effective monitoring or evaluation is undertaken with regard to research expenditures, their outcomes or the impact of the approximately 2000 approved R&D projects currently underway (Interviews: MSRT). Even data, such as a list of the most important R&D results in Iran over the past several years, which might make such an assessment possible is not available. The lack of specific goals and desired impacts of the research activities funded through the MSRT and the absence of monitoring and evaluation capabilities and activities are serious flaws in the management of the innovation policy system.

User-Producer Linkages

Within the MSRT, technology development falls under a separate Vice Ministry from that of research. Despite the absence of formal guidelines and policies in the area of technology development, MSRT has launched a series of studies in the area of S&T as the basis for the design of new policies in this area.

In the development of linkages between producers of research and technology development (RTD) and the enterprise sector, IROST plays a central role. Established in 1980, IROST's mission is to support, financially and intellectually, inventors, innovators and researchers mainly in the private sector. It also conducts research and its role in biotechnology research and technology transfer to industry in Iran will be discussed in Chapter 4.

IROST provides technical and some financial support to start-up companies, particularly those manufacturing products that substitute for imports. To some extent, therefore, IROST acts as a granting council, receiving proposals from researchers in small and medium-sized enterprises when they require funds to develop a prototype, peer reviewing the proposals and making awards. This is part of a joint program

MSRT/ IROST/ MPO/ private sector/ institutes to support innovation projects up to the experimental development scale and encourage public-private partnerships in the process. Thus 40 per cent of the funding comes from private industry and 60 per cent from the MPO. MSRT and IROST are the intermediaries.

IROST shapes some technological development priorities through these grants and is oriented towards support for small and medium-sized enterprises. IROST also provides a range of support services to investors and innovators. This includes recommending them to banks for low interest loans, assisting in the transfer of technologies developed by researchers to third parties and obtaining production licenses and production facilities from the Ministry of Industry and Mines for innovators following the pilot plant stage. More substantial policy instruments, low interest loans, tax incentives, such as, the exemptions amounting to .02 percent of total annual sales for companies that establish their own R&D units and a 30 million USD fund for research, technology development and innovation in high tech sectors are administered by other government bodies, namely through the Ministry of Industry and Mines. IROST, therefore, does not have sufficient funds to move products to market or create spin-off companies in most sectors, though it does provide technical and intellectual support to researchers for this purpose. The MSRT thus plays a relatively small role in the funding of innovation overall, but it has a strong position in scientific research and technological development and in biotechnology which is relevant to the present study, it has been more active on the innovation front as well (see Chapter 4).

Following upon the experience in setting up the Isfahan Science and Technology Town, which grew out of IROST's Isfahan Research Center, IROST decided to turn their other provincial branches into science and technology parks. These new S&T parks took their funding with them, thus leading to a decline in IROST's budget in recent years. Since then and in view of the multiplicity of actors currently involved in setting up science, technology or industrial parks in the Tehran area and in the provinces, including a large number focused on high tech sectors[10], it is uncertain what role IROST will be playing in this field in the future.

Conceptualizing Innovation Systems

Within the MSRT confusion with regard to basic concepts such as science, technology, invention and innovation remains and the persistence of a linear approach to the innovation process is evident. This is reflected in the separation of scientific research from technological development in policy planning and programming.

Prior to the Third Five Year Plan, the position of Vice Minister for Technology in the Ministry of Higher Education was held by the Head of IROST. Now there are two separate posts. IROST receives its budgetary allocation from the MPO with whom they negotiate directly. Their budget is thus not included in that of the MSRT and to some extent their activities are independent of the Ministry to which they are attached.

[10] TCO, for example, established the Pardis Technology Park near Tehran in 2001 and the Iran Industrial Estates Corporation, affiliated with the Ministry of Industry and Mines was set up by Parliament to develop knowledge intensive industries within metropolitan areas. A Software Technology complex was set up in Tehran in 2000 and a Telecom Research Centre was also established under this programme. This seems to have become part of the mission of the High Tech Centre affiliated with the Ministry of Industry and Mines.

This distinction between the MSRT and IROST is reflected in work currently underway on the National Technology Development system, a project stemming from the new tasks assigned to the MSRT under the Third Five Year Plan and intended to provide the basis for infrastructure, legal framework, goals, strategies and priority setting in the area of science, technology and innovation.

At the request of the MSRT, a Technology Advisory committee (TAC) was established within IROST to review the National Technology Development System and to advise the Iranian government on long-term technology development planning (Abassi et. al.: 2003). As part of this mission, IROST commissioned a number of studies both in-house and from outside consultants to benchmark technological development in Iran. Its approach, however, was not coordinated with that of the Vice Minister for Research. The latter contracted with the System Engineering and Management Company, to develop a Management System for the development of science.

This reinforces an artificial distinction between research and technology development adding to the already problematic exclusion of traditional sectors and downstream industries from the 'innovation system' as it is currently operationalized through the practices of major innovation policy-making actors. Moreover, it reflects a generalized misunderstanding within the MSRT of basic concepts related to the process of innovation and the nature and functioning of innovation systems. Under such conditions, it is unlikely that an integrated science and technology policy can be completed in the short term and even less likely that such a policy will be centered on creating a culture of innovation within the Iranian society and economy or provide the stimulus and support needed to strengthen the national system of innovation in Iran and the innovation dynamic within it.

2.3 The Technology Cooperation Office

The Technology Cooperation Office (TCO) traces its origins to the "Office of Scientific and Industrial Studies" founded in 1984 and given the task of providing scientific and industrial advice to the President. At the time, there were few scientists and technicians in the bioscience sector and no infrastructure existed to produce the enzymes and reagents needed for biopharmacy. Policies and programmes to stimulate and support collaborative R&D partnerships at home or abroad did not exist. TCO thus began to fill these gaps with a focus on the 'technology' side rather than on research. Overtime it developed its contacts with foreign scientific research institutions and was renamed the "Technology Cooperation Office" to emphasize its mandate in promoting international cooperation in the field of advanced technologies. TCO promotes joint research projects between Iranian institutions and foreign industrial and scientific research centres.

TCO is organized into sector-specific departments and a Research and Planning Department. These maintain very light staffing structures. The TCO bioscience department, for example, includes five areas, agriculture, medicine, biopolymers, nutrition and environment but has only 10 staff members. The bulk of the individuals involved in TCO bioscience activities are "advisors" to TCO for specific projects, about 20 per field. For the most part, these are researchers based in their home institutions and each advisor manages at least one international project.[11].

Nominally, its sector-specific departments cover a broad range of 'technologies', but in practice its current focus and strength lies mainly in the biosciences, nanotechnology and advanced (composite) materials.[12] In these areas TCO undertakes the following activities:

- Builds support for biotechnology among policy-makers by creating a bulletin to inform policy-makers of recent bioscience findings and their economic utility. Similar activities are beginning in nanotechnology.

- Stimulates the creation of small biotechnology firms spinning off from existing biotech companies and institutes through low interest loans

- Identifies partners for collaborative research and funds new projects in both state and private sectors.[13] TCO views its role as "end product oriented", that is, it supports "projects that may result in a commercializable technology" and

- Reviews and assesses national policy documents in the area of science and technology and provides advisory services to the President on these.

A number of weaknesses persist in TCO's sector-based activity portfolio. Two of these weaknesses stand out in particular and are typical of the functioning of the Iranian innovation policy system overall. The first, stemming from the linear perspective that still characterizes policy-making in this area, is the dominance of academic criteria as the standard for evaluating research quality. This derives from the link between higher education and scientific research. Research institutions such as the Iran Composite Institute, for example, lose relevance if their researchers do not collaborate closely with industry. Yet to do so hits up against the long standing prejudice in academic circles against research that builds upon theory rather than produces theory.

The second lies in the traditional habits and practices of governmental bodies and research institutions in Iran to work in parallel rather than to collaborate. In the case of biotechnology, research in the same areas and sometimes on highly similar projects is underway. Having multiple projects of this sort is not in itself negative. What is a problem, however, is the lack of cross fertilization and information flows across projects and ministries/institutions in which they are located. Where collaborative linkages remain weak, ministries that are involved in upstream or downstream

[11] In agriculture, for example, the focus is on assays to screen and develop wheat and rice that is resistant to fungal infection; in biopolymers a joint project between the Polymer Institute of Iran and the Biomedical Research Centre of the University of Vienna is developing biodegradable cartilage from chitosan extracted from shrimp in the Gulf.

[12] In addition to these three areas, TCO covers aerospace, information technology, software, industrial processes, civil engineering, infrastructure, energy and also undertakes studies on technology development and technology management. http://www.tco.gov.ir/tco-briefe.html

[13] TCO supported the creation in 1999 of the Iran Composite Institute which is attached to the Iran University of Science and Technology. The institute carries out academic research and training through to the Ph.D. level. It also does research on designs and constructs composite structures collaboratively with local firms, such as a joint research project with industry to redesign the nose cone of a helicopter using new composite materials and a new shape.

activities do not provide the demand nor subsequently supply the users for the output of research and technological development when they are not involved as collaborators in these projects. Awareness of the utility of composites in a critical upstream industry, oil and gas, for example, remains low. As a result, although that ministry could provide the inputs for the development of polymers and glass fibres, these continue to be imported.

In addition to its sector-specific departments, in 1998 TCO created a Research and Planning Department with a view to meeting the growing need within TCO for technology support and advisory services. The department is mandated to study the technology sourcing and finance problems of the private sector as part of the government's growing interest in promoting private sector involvement in the development of high tech industries.

Over the next several years the Department expanded to include six divisions: Research, Planning & Supervision, Jurisdiction and Contracts, Technology Evaluation, Information & Library and Training. The latter five divisions have technical support functions in the transfer of technology process including preparation of contracts, dispute settlement and project evaluation and in providing planning, budgeting and monitoring as well as data management and training services for TCO itself. The former is mandated to undertake the following types of studies and activities:

1. Studies of the policies and development plans in successful countries,
2. Analysis of the factors affecting development and progress in Iran
3. Provision of assistance in developing the technological culture
4. Fundamental research about technology
5. Development of concepts and methods for technology transfer
6. Evaluating the existing status of technologies in Iran
7. Forecasting the process of technology development in Iran and other countries
8. Helping to found technology analysis centers and establishing relations with similar centers and also between the researchers.

Source: http://www.tco.gov.ir/tco-briefe.html

A number of these tasks overlap with those of the High Tech Industries Centre (HTIC) affiliated with the Ministry of Industry and Mines. At the same time, a number of critical functions are not carried out at all.

2.4 The Ministry of Industry and Mines

The Ministry of Industry and Mines contains line departments which nominally monitor and make policy for industrial sectors, a number of departments composed of established organizations and companies that support the development of industrial firms and a new department, created under the Third Five Year Plan, the "High-Tech Industries Center" (HTIC) to stimulate the creation of enterprises in 'high tech' sectors.

The function of the line departments has been described as 'strategic planning'. The development of a strategic plan for the automobile industry illustrates the comprehensiveness of this process and the collaborative linkages that are being forged to give effect to the plan. In view of the high level of urban pollution in Iran, the auto plan focuses on the conversion of buses and cars to natural gas. This obliged the MIM to work closely with the Ministry of Petroleum. It also required new approaches to attract large foreign assemblers with new engine and transmission technologies that enhance the efficiency of internal combustion engines into the industry and to build consensus on the replacement of the Paykan by the Samand, a national car that shares a common platform with Renault/Nissan and for which the body has been designed in Iran.[14]

To create an incentive for technological upgrading and innovation, competition in the industry is to be further developed and tariffs lowered. Iran's advantages in this sector lie in a strong steel industry with a state of the art alloy steel plant and thus the ability to produce good quality components as well as the relatively large number of researchers and technicians in the auto sector. But unlike other major automobile producing developing countries, Iran's small and medium-sized enterprise sector is tiny and lacks the technological capabilities needed to play a role in this sector as suppliers to the component manufacturers and automobile assemblers. The absence of policies and programmes to support technological upgrading in the SME sector within the context of an integrated approach to the innovation system is a major obstacle to growth in the future.

Having brought the Ministry of Petroleum on-board in the development of natural gas, they are now pressuring the MOP to use more oil in downstream products especially polymers. Parallel to this is the work going on at the MIM's own research centre on ceramics and foamy aluminum catalysts and this work has been scaled up to the pilot stage. Despite these advances, the proposed transfer of the National Petrochemical Company (NPC) to the Ministry of Industry and Mines was not approved and the consequences of this can be seen in the analysis of the oil, gas and petrochemical sector in Chapter 3.

Although the Ministry of Industry and Mines appears to be quite active in developing a strategic plan for the auto sector and has approached this process from a holistic and innovation-oriented perspective, the same cannot be said for pharmaceuticals. In view of Iran's eventual entry into the WTO, however, there is a clear need to build a biopharmaceutical innovation system by deepening production capabilities in the enterprise sector, strengthen their linkage to research and to the health care system and develop policies to stimulate and support entrepreneurship and innovation. For this to take place, however, line departments at the MIM must overcome the production-oriented legacy of the past and the confusion that reigns over concepts such as 'manufacturing' when it comes to pharmaceutical products where, in value terms, critical inputs such as active ingredients are not produced locally but imported.

In addition to the line departments, there are several departments within MIM active in supporting technology development in industrial firms. These are the

[14] The Khodro R&D center is reported to have sound technical capabilities in a number of areas, a good workshop and test facilities. It is presently developing a compressed natural gas engine to EU standards for use in the Samand.

1. Industrial Development and Renovation Organization (IDRO)
2. Small Industries Organization
3. Iran Mineral Industries Development and Renovation
4. Iran’s Standard and Industrial Research Institute (ISIRI)

MIM also supports technology development through several financial programs such as the auto industry fund, industrial technology assistance program, electronic development fund, industrial research and IT training program, productivity program, research & study of the SMEs research program, and research production program. These warrant further study to assess their effectiveness over time.

2.5 The High Tech Industries Centre

The Department for High Technology Industries, also known as the High Tech Industries Centre (HTIC), was created in 2000-2001, as part of the changes introduced under the Third Five Year Plan. Like IROST, its budget of between $35-40 million per year, comes directly from the Management and Planning Organization and does not pass through the Ministry of Industry and Mines. Thus artificially creating a separation between the HTIC and its host ministry.

HTIC has a staff of 50 persons of which 25 are professionals and 25 support staff. Like the TCO it has a light staffing structure. There are nine committees each of which is headed by a project leader on contrast to the HTIC. Several of the HTIC project leaders are also ‘advisor-consultants’ to TCO. Collectively, the network of scientists and other experts associated with these committees constitutes a group of some 300 collaborators.

Six of the HTIC’s committees are sector (technology)-based and focus on software and information technology, electronics, civilian aerospace, laser and optics, new materials and biotechnology. The work of the Biotech Committee is further sub-divided into five branches: medical, industrial, biomaterials, agro biotech and bioinformatics. These sectors closely resemble the sectors and sub-sectors that are the focus of TCO activities. However, the tasks undertaken by the HTIC committees differ. In particular the HTIC has used these committees and their network of members to survey the strengths and weaknesses of the sector in relation to global market and technology trends and create consensus among different high-tech industry agents, primarily R&D centres and universities on a set of priorities for the development of the sector. The ‘action plans’ that are being drawn up go beyond the strictly scientific to include technical, marketing, investment, legal, management and engineering information and assistance, equipment for laboratories, the creation of incubators and the identification of tax laws or regulations needed to strengthen the private sector.

In addition to its sector specific committees, the High Tech Industries Centre has three research divisions with a focus similar to that of the TCO. One of these divisions has been set up to survey development models in other countries with a view to understanding the factors that enabled them to advance technologically. This task is identical to that being undertaken by the TAC within IROST. A second research division focuses on economics and a third on the Management of Technology, an area that is not central to the work of either TCO or IROST. Within the Technology

Management Group tools for technology assessment and technology foresight applicable at the sector level are being developed and training of M.Sc students in the Management of Technology Programmes at Sharif and Allameh Universities provides an important addition to tertiary education in the field of science, technology and innovation policy and practice in Iran. Collaborative efforts are needed to create broader awareness and greater consensus in the policy community on an Iranian approach to innovation-oriented development.

2.6 Assessment

Despite the move towards a knowledge-based economy since the Third Five Year Plan, innovation has yet to become a strategic goal of policy-making in Iran. Policies and programmes developed by principal actors in the innovation policy system continue to focus in linear fashion on the supply of 'upstream' human and knowledge resources as generated by the education, scientific research and technological development processes. The conceptual approach to innovation in terms of a 'National Technological Development System' reinforces this focus on the supply of research and technology, whether from within the emergent system or through international collaboration and licensing from abroad and on the role of technology in the growth of industrial output. Few policies, however, are directed towards stimulating the learning and technological mastery needed for innovation, and in the absence of such policies, the overall structure of the economy provides little incentive for doing so.

Within the existing policy framework, too little attention is paid to the central actors in an innovation process, which are the enterprises themselves, and to innovation as an interactive process involving users and producers of knowledge, goods and services. Translated into policies and practices, this approach to science and technology policy virtually omits innovation that is pulled by demand, excludes sectors other than the so-called 'high tech industries' from the innovation system and ignores both the role of small and medium-sized enterprises and of enterprises located in 'traditional sectors' in technological upgrading and innovation. The system is thus segmented and lacks a dynamic process of innovation at its core.

Current policies and policy-making practices have contributed to these shortcomings in the innovation system. A clear understanding of the integrated nature of innovation systems is still lacking within policy-making circles. So, too, are a national vision and a set of national goals and priorities, the absence of which cannot solely be attributed to the political controversies stemming from the co-existence of Parliamentary and Parallel governance systems. Much more can be done within the existing organizational structure and in the context of existing mandates, if traditional habits and practices that limit information flows and collaborative behavior can be overcome. The following recommendations are made with this end in mind. They build upon a tacit division of labor that has begun to emerge with respect to 'high technology sectors' in the economy and suggest that this be generalized. In the distributed policy- making approach taken here, new ways of dealing with missing functions and linkages are also proposed.

There is an urgent need to create a national vision in which innovation would be seen as the key vehicle in economic growth and from which goals and priorities can be derived for the nation. It is within such a framework that new system- wide innovation-based initiatives might be developed that combine the actions of diverse ministries, each of which, through the setting of sector-level goals and priorities and the design of policy instruments can give effect to the goals of these national initiatives in a coherent fashion without recourse to a hierarchical policy-making system. This approach widens the focus of policy-making to include all sectors and potential actors in the innovation system.

Currently most goals and priorities are set within individual ministries through traditional top-down bureaucratic decision-making processes. More recently, however, two attempts have been made to introduce a bottom-up approach involving experts in the definition of goals and short-term priorities. The first was undertaken by the HTIC of the Ministry of Industry and Mines for a number of high tech sectors.[15] The second involved a two-step survey of experts from universities, research institutes, government, industry and the service conducted by IROST in collaboration with the MPO. It was designed to establish a list of technology priorities in 14 different fields to serve as the basis for planning and investment in RTD activities in the fourth five-year plan.

This bottom-up approach recently introduced in Iran for the establishment of research and technology development priorities should be further developed and generalized to the system as a whole. A number of alternative ways can be envisaged for doing so. But the greatest visibility and hence the highest impact on building public awareness and developing a clear understanding of innovation within the development process on the part of high authorities would be to involve the people in a policy forum on science, technology and innovation.

The Supreme Council for Science, Research and Technology could organize policy dialogues and stakeholder meetings to engage in technology foresight activities through which a common understanding can emerge on the role that science, technology and innovation need to play in the resolution of social, economic and environmental problems. In this national forum, goals and priorities can be set with respect to new medium- and long-term initiatives.

Recommendation: Improving coordination and coherence in horizontal innovation policy-making

As in distributed knowledge systems more generally, distributed policy making enables policy coordination and coherence to take place with a reduced need for centralized, hierarchical decision-making processes. This framework facilitates task-oriented behavior through management committees that combine the principal of an explicit division of labor with regard to critical policy tasks and functions within the innovation system and the variable geometry that brings together that set of ministries and policies needed to support systems-embedded processes of innovation in and across productive sectors or in problem areas targeted for attention at the national level.

[15] See the discussion of HTIC activities in Chapter 3.

Following upon the partial implementation of the Third Five Year Development Plan a tacit division of labor has begun to emerge among key players in the innovation policy-making system and this provides a basis for the adoption of a more explicit division of labor. TCO, for example, began to engage in technology foresight activities at the national level and to assess policy proposals and strategic programmes that are brought before the President and Cabinet from a sector and task neutral perspective. Their work on technology foresight in combination with the technology priority-setting activities undertaken by the MIM, IROST-MRST and MPO provide a core group of actors to develop the policy dialogues and stakeholder meetings envisaged above.

Unlike Ministries such as MOP, the MSRT has no state-owned companies within its organizational structure and does not seek to create them. Education and scientific research linked to it are two of the main mandates of the MSRT and have been its traditional strengths. In addition, within the MSRT, IROST is focused on technological development, which it pursues up to the pilot stage and then seeks industrial partners to whom 'technology' can be transferred. They do not plan to bring their projects to market nor have they the funds or expertise to support the creation of spin-off companies. The strength of the MSRT thus lies in its knowledge of the research process and its ability to work closely with Universities and network across the research divisions and departments of other ministries. They are a natural complement to Ministries, such as the MIM, MOP, Ministry of Energy or Ministry of Jihad-Agriculture, whose focus is on production and whose operations are thus related more directly to the activities of the firm.

One might expect that these production-oriented Ministries would thus be centers of excellence in innovation support services and policies, but there are internal organizational problems that still need to be resolved before these Ministries can play this role. In the case of the Ministry of Industry and Mines, for example, there is a serious lack of information exchange and collaboration between the High Tech Industries Centre, line divisions and departments within the Ministry. This has contributed to innovation policies and practices in which firms in traditional sectors and small and medium-sized enterprises are excluded from consideration. The awareness building process discussed above will help to widen this perspective and other incentives, discussed below, can be put in place to stimulate closer intra-ministry collaboration and linkages to the enterprise sector.

Vertical integration within the MOP has created a different set of problems, related more to the lack of an interactive dynamic with upstream as well as downstream enterprises, that might stimulate a move beyond narrowly conceived problem-based innovation to longer term research efforts aimed at the development of new products and processes. A number of recommendations specific to the oil, gas and petrochemical sector will be presented in the next chapter. These observations, however, point to a critical need to improve communications as much within as between Ministries.

Strengthening information and knowledge flows can enhance policy coordination and coherence. This will require efforts to create usable information and to set up the processes through which data collection can be maintained on a continuous basis. Improving the data collection within all ministries is one way to begin this process.

Another is to design and carryout periodic innovation surveys.[16] Distributed policy-making and implementation provides a useful tool in carrying out both tasks by bringing together participating Ministries and universities to set up joint training programmes, to design and undertake the survey and analyze the data.

Incentives, however, must also be present to encourage the use of such information in the policy process. This can be achieved by requiring that the design of science, technology and innovation policies contain explicit programme and project selection criteria and that programmes and projects include specific performance goals by which these are assessed in annual results-based budgeting reports. Mandating policy and programme reviews at regular intervals will reinforce conformity with these objectives and strengthen coordination and coherence in innovation policy-making.

In addition to their role in inducing information exchange and collaborative activities, monitoring and evaluation are critical for adaptive policymaking. If five-year planning cycles continue, major programmes and policies should be evaluated at three to four year intervals. The MPO currently does some macro monitoring of budgets but has no criteria by which to monitor and evaluate policies and programmes. These tasks might be carried out by the MPO as an extension to its existing functions provided that the MPO has no role to play in the design or implementation of such policies and programmes. This ensures the impartiality of monitoring and evaluation processes and the utility of their results for adaptive policy making. Collaboration between the MPO and the MSRT will be essential in training researcher in monitoring and evaluation techniques through courses set up within universities that have established management of technology programmes and in developing the process through which policy, programme and project monitoring and evaluations can be carried out.

Management & Evaluation System. It is proposed to initiate a formal process at MSRT to prioritize among various projects, assess the validity of projects before they start, monitoring activities during progress, and evaluation and audits on research completion.

Recommendation: Building research and technological capacity through joint ventures, licensing agreements and strategic partnerships with foreign firms and research institutions

Licensing has been practiced in Iran as a means to produce a variety of products in the oil, gas and petrochemical sector as well as in pharmaceuticals for the domestic market, but incentives for learning through licensing and more recently through joint ventures have been few. This is related to the continued emphasis in Iran on production rather than on innovation as the core of the development process. Little attention has thus been paid to the need for domestic capabilities in Iran, at least as measured by policies in place. More attention has been given to short term economic benefits from co-operation and licensing. But getting the most out of these agreements

[16] Innovation surveys have become important tools for the collection of policy-relevant information across all OECD member countries. More recently they have been carried out in a large number of developing countries including Brazil, Argentina, South Africa, Malaysia and Singapore.

in the long term should warrant including them as major instruments in a national innovation policy and designing them accordingly.

There are many ways to design and implement schemes to stimulate such learning and they generally have a high value for the long-term development of innovative capabilities and industrial development.

As a first step in this process, these important contractual arrangements should be put more firmly into a national strategy for building up the domestic R&D capacity and developing infant as well as more mature industries. Without taking the comparison too far, valuable insights can be learned from the Norwegian experience with their concession system and technology agreements. Having little oil and gas competence in the early 1970s, the Norwegian government set out to create a framework for domestic build up of know how and expertise, including advanced R&D in research institutes and universities. Oil companies with interests in participating in the oil and gas activities, entered into agreements under the flexible concession system to invest in research and development in Norway. Companies not willing to do this were left out of the process. Linked to this was an infant industry policy via Statoil, which during a critical period of time ensured contracts to the Norwegian subcontracting system.

Data also needs to be collected on past licensing practices. This can take place through the merger of existing registries of licenses and joint ventures currently located in a large number of ministries including the MOP, MOH, Ministry of Energy and Ministry of Justice. These data can form the basis for a restricted on-line distributed information system and make possible needed research into factors that have been a disincentive to learning through licensing and joint ventures in Iran and contribute thereby to an effective policy environment to deal with this problem.

In recent years, international strategic partnerships have become popular among enterprises and research institutions as a means of acquiring new knowledge, technologies and learning. Some of the Iranian research institutes already have such partnerships with some foreign research institutes on a smaller scale. Such partnering can be further strengthened. There is no evidence of Iranian enterprises entering into such partnerships either with foreign enterprises or research institutes. Iranian enterprises can be encouraged to form such international partnerships.

Recommendation: Building user-producer links

Innovation is fundamentally an interactive process and user-producer interactions are at the core of a dynamic innovation system. Users may be downstream enterprises, which are clients of upstream firms as in the link between oil and gas producers and petrochemical firms or petrochemical firms and downstream industries such as polymers, textiles and automobiles. Users might also be located in the service sector or in the ministries. The health care system, for example, is both a direct user of medical research and a consumer of drugs produced by pharmaceutical firms. Health care policies will thus have an impact on the selection of research directions to pursue and the choice of production techniques and sources of technology. In a well functioning innovation system, there is a critical need for linkages between the demand –side interests of users and both the knowledge and goods producing sectors.

Frequently however, demand is only weakly articulated, though the need for information, know-how and embodied technology is needed to sustain competitiveness in a sector. Policies have a strategic role to play in strengthening these linkages.

Targeting the supply of R&D. Much of Iran's R&D activity and its R&D financing takes place within Ministries. In the petroleum/petrochemical sector, for example, this tends to exclude private sector engineering firms. To the extent that Government has moved to support the development of the private sector, this legacy from the past is a serious obstacle.

The growing attention in many industrialized countries to the need to build bridges between knowledge producers and users has resulted in a wide range of policy initiatives to spur public-private partnerships and science-industry relations. These include funding mechanisms to stimulate the formation of R&D consortia that bring two or more firms together to develop a new technology, solve a common problem or build a common interface and grants to underwrite the costs of patenting and of technology transfer from universities and public sector research institutes to industry.

Innovation Challenge Funds of this sort are recommended for Iran, as a means to improve linkages, stimulate knowledge transfers, provide opportunities for long-term investments in R&D and encourage strategic change in the university sector. The more relevant university activities are for industry, the more likely are private investments and co-funding from that industry. Innovation Challenge Funds that include a matching-grant element have been successfully implemented in countries such as India, Brazil, Canada, Turkey and the European Union. These typically call for invitations to *submit research proposals jointly* by the private sector and the publicly-funded laboratories (including universities), with each party meeting part of the costs and supplemented by the matching funds. For instance, the Turkish Technology Development Foundation received a World Bank credit of around $ 10 million to undertake priority research tasks initiated by private companies jointly with a technical university.

Targeting the Demand for Technology. While competition pushes firms to innovate, demand pulls new knowledge into economic production. Demand is thus one of the key drivers of innovation. All to often there are market failures that result from the lack of expression of these needs through the mechanism of the market. For example, there is a clear need in Iran today to focus on upgrading in downstream industry and in users of upstream products such as refined oil for automobiles, amino acids for pharmaceutical industries or diagnostic kits for local diseases.

The Innovation Challenge Fund discussed above can help to stimulate such demand but can only do so if the need is already felt by these firms, they are aware of the existence of such a fund, have the network required to create a consortium and the time to prepare a project. Experience in the European Union with such mechanisms has shown that special services must be made available to small and medium-sized enterprises to ensure that they are not excluded.

Even then, critical demand is too weak to be heard. The petrochemical sector, for example, has important forward linkages to end-user industries like textiles, plastics, travel goods and various end uses of polymers. As many of these industries are not competitive and lack innovation capabilities, they will not provide sufficient pressure on the petrochemical sector alone to produce the quantity and quality of products they need to develop and grow. Relative to the abundance and future growth of petrochemical production capacity, the end-user industries represent too small a stimulus. Hence, the petrochemical sector itself is organizing innovation more or less by command, which is through decisions internal to the Ministry of Petroleum and its subsidiary NPC and in function of five-year plans.

To compensate for this and to help implement a more market-based decision making mechanism for innovation down the value chain, Government could take an active role in organizing advanced demand. Some countries are more active in using such instruments than others, and Sweden has for example a well-known tradition. Such demand can be stimulated through government technology procurement programmes that support or fund technological development that would otherwise have no market. The buying power of public sectors is enormous if coordinated to strategic ends. The typical mode of technology procurement would be to let government institutions articulate demand for certain products or technologies and procure them at a price that includes the necessary research and development costs. Such programmes, however, should only be launched as part of a long-term industrial policy.

Upgrading SMEs. Small enterprise promotion could benefit from the development of of Market-oriented Business Development Services. Technical cooperation projects can be designed to transform state service agencies into contract consulting and research mechanisms. The services typically provided are: Entrepreneurship Training, Advisory & Facilitation Services, Human Resource Development, Business Management, Marketing, Mentoring, Counseling, Networking, Financial and Personnel management, Legal assistance, and Export Assistance.

Business Development Services can be made more affordable and effective by letting SMEs themselves choose between service providers in a competitive market place. Vouchers systems can be proposed for further study, where the government gives selected entrepreneurs a voucher of designated value, and the entrepreneur is then empowered to choose the service provider from a list of accredited providers. State plans and development cooperation thus serve to stimulating market demand for business services and not on subsidizing the supply from service providers.

As the creators of new ventures are typically young men, the reservoir of entrepreneurs can be enlarged by pro-actively raising the participation of women as well as those under the age of 25 and over 45. Courses that promote entrepreneurship development and focus on learning and innovation can play a particularly important role in strengthening a culture of innovation when introduced into curricula at the high school level and for students graduating from universities especially those in business schools and disciplines appropriate for self-employment

Starting in 1988 in Argentina and now under UNCTAD auspices the EMPRETEC Program has spread to 24 countries. It provides a good platform for training of entrepreneurs facilitating access to finance and markets and continuing the support through Empretec associations. The early initiation of an Empretec program in Iran is recommended.

SME chambers and associations can play a crucial role, not just in advocacy, but in information-exchange, training and counselling, compiling and disseminating statistics, networking between individuals and enterprises at the national, regional, and international levels. As fee-paying membership organizations or as semi-governmental entities, they must be given autonomy to represent and serve their SME clients.

Recommendation: Developing clusters and incubators of knowledge-based activities

Inter-firm cooperation among firms and related services is frequently regarded as a major stimulus to innovation and to regional development. Clusters are the result of a spontaneous tendency of SMEs to locate close to each other, but there are also organised efforts to set up clusters from scratch, mainly through EPZs and technopoles or science parks, which are artificial agglomerations of firms resulting from technology and export policies.

Iran has experimented with a number of different initiatives. Currently there are three free industrial and trade zones already established in the Persian Gulf, (Qeshm, Kish and Chabahar), and three others are in the planning stages (Abadan-Khoramshahr, Jolfa, Bandar Anzali). In addition twenty special economic zones have also been created and one of these, the Petzone will be discussed in Chapter 4. In Iran the free industrial and trade zones were developed mainly for job creation purposes, and therefore were set up in poor and underdeveloped regions to attract both domestic and foreign investment thanks to duty-free access to imported inputs (but not to exemptions from labor and financial regulations). Most of these are still at their early stage of operation, but there are some cases which show how such zones can be used strategically to promote regional economic development and unlock disadvantaged areas from stagnation.

In this context, it should be reminded that success in enhancing the share of technology–related exports and participating profitably in export markets is often based on productive linkages between the small producers and large foreign corporations, as well as with local research organizations, civil society and technical cooperation agencies. The key role of the government is to formulate policies, fiscal measures and related organizations that promote the level playing field and an outward-looking trade strategy.

More recently, Iran has also already started to explore and disseminate the concept of incubators for early-stage enterprises and technology parks for commercializing its research outputs. The IT incubators at Isfahan Science & Technology Town, work in Kerman (which includes Darya -- the first Venture Capital Fund), and the Paradis Techpark under construction near Tehran are promising developments. With regard to the promotion of technology parks and incubators, a step-by-step program is recommended, through which an overall strategy can be elaborated into which such initiatives can be placed and through which coherence and complementarity can be enhanced. The program would:

- Prepare a strategic framework identifying the policies, regulations, incentives and other forms of support required from the Government and the private sector.
- Develop a business model of good facilities and service practices that is efficient, effective, and financially sustainable.
- Create structured linkages for experience-exchange, mentoring, and out-sourcing between universities, research, productive sector, service providers, public organizations, and between the parks and incubators themselves.
- Establish association and strategic partnerships with counter-parts within Iran, in the region and internationally.

However, it has to be considered that a technology park represents a major investment ($ 10 million and more), over a long time horizon (up to a decade) from conception to maturity. It is therefore essential to determine, through competent feasibility analyses and business plans, whether the conditions for attracting research and technology organizations exist, and whether "patient money" is going to be available. Additionally, it has to be emphasized that while Iran has made a good start in launching a technology business incubator and tech-park program, incubators are not the only possible measure for promoting technology and there can be other effective vehicles for generating new start-ups and employment.

One of these is the stimulation of industrial clusters. As in the case of dried fruits or carpets, the agglomeration can be spontaneous and be directly promoted by enterprises (mainly starting small) producing and selling related and complementary products and services. Their participation in a strong infrastructure, production supply chain, labor and markets, at the local, regional and cross-border levels, facilitates cooperation-for-competition. Once the clustering starts spontaneously based on local endowments, provincial government agencies and private support services can help catalyze the development of design, marketing, credit and technology to promote competitiveness.[17]

Policy interventions, however, should be confined to revitalizing only selected clusters with high growth potential, and not supporting agglomerations of tiny firms in an indiscriminate manner. Experience shows that focussed measures (e.g. the creation of technical schools, research centres, export promotion boards, quality certification institutes) and trigger mechanisms (e.g. strengthening business associations, subsidizing export initiatives, promoting brand names and new product/location images, establishing strategic alliances among public and private actors) can play a role in stimulating and supporting change, tacit knowledge flows and interactive learning.

With suitable help in the form of technological assistance, financial support and a stimulating environment, clusters can produce goods with a high technological content and become competitive on a global scale. In particular, the following good practices should be kept in mind when implementing cluster development programmes:

[17] It is noteworthy that India has 300 modern SME clusters and 2,000 artisan rural clusters. The whole SME sector employs 14 million, contributes 40 % of industrial production and 35 % of exports.

- Initiatives should be defined and implemented with bottom-up involvement of the main local interest groups, both public and private.
- Recipients themselves should be in charge of the needs assessment process, and not just involved in the programme as end-users.
- The target of support measures should not be a single enterprise, but a network of enterprises. Providing common services has two main advantages: (i) it lowers transaction costs; (ii) it helps generate interaction between enterprises, improving their efficiency and maximizing the potential of the group through the development of mutual learning.

CHAPTER 3. DEVELOPING DOWNSTREAM CAPABILITIES IN IRAN: THE OIL, GAS AND PETROCHEMICAL SECTORS

3.1 Introduction

Iran is a major player among the oil and gas as well as petrochemical producers in the world. Although the main focus in this chapter is on petrochemicals, an analysis of the petroleum industry (oil and gas) is also included, as it allows a more systemic perspective on the development, strengths, weaknesses and possible failures in the innovation system more broadly. Petroleum and petrochemicals have tight linkages as the former provides feedstock to the latter, and they are subsumed under the same Ministry of Petroleum and hence share some institutional framework conditions.

The increasing importance of oil throughout the period following World War II, combined with the price hikes of the 1970's made Iran one of the major actors in the global market for oil and one of the most sought destinations for foreign oil companies. The petrochemical industry had less strategic interest for foreign oil companies, and this enabled domestic capacity in R&D and related areas to be more easily developed than in the oil and gas sector. .

The Islamic Revolution in 1979 and the war with Iraq that followed soon after and lasted until 1988 significantly influenced the situation in the oil and gas and the petrochemical sector. Most of the petroleum facilities were seriously destroyed by the war. The destruction of wells and reservoirs during this period was considerable: While Iran typically produced 6 million barrels per day before the revolution, production fell to 1,45 million barrels a day at the beginning of the war and averaged only 2,4 million barrels a day throughout the war period. Iran currently produces 4,2 million barrels per day, up from 3,6 million barrels per day in 2001. As foreign experts left the country since the late 1970's, Iran was left with little expertise and know-how.

The destruction of petrochemical plants and oil refineries was likewise serious, and many were devastated or partly destroyed. The Abadan oil refinery, completed before World War II was one of the largest in the region. Completely destroyed in the Iran-Iraq war, it was rebuilt in 1985 after Iran had regained momentum in the war, but the refinery did not come on stream until 1989. Its production capacity fell to 260 000 barrels per day, far below the pre-war peak of 610 000 barrels per day. With regards to petrochemicals, the Bandar Imam Petrochemical complex (then called the Iran-Japan Petrochemical company) located not far from the Iraq border in the Persian Gulf, was seriously damaged. As a result, the capacity for refined oil products in Iran dropped from 1,081,000 barrels a day in 1977 to less than 600,000 barrels a day during the war. This had resulted in huge imports of oil products, which created a situation whereby the government gave priority to rebuilding and expanding the petrochemical sector.

3.2 The Post-war Reconstruction

In addition to the Abadan oil refinery, several refineries were constructed during a coordinated programme in the mid 1960's. Although most attention in the post-war period was focused on building up petrochemical production, by 1992 the oil refining sector had been largely reconstructed and consisted of 6 refineries and this has been expanded to 9 refineries today. Still, Iran imports a significant share of the oil products it consumes. This is both high and wasteful due to heavy subsidies to the benefit of the consumer. The combination of this with a very old stock of cars (average age 17 years) and a sub-standard quality of gasoline coming from the old-technology oil refineries and imports, lead both to heavy pollution in the cities as well a to a significant lock-in to a out-dated auto-related technological system

Another feature of Iran's oil refining industry is the high output of residual fuel, approximately 30% compared to 5% from Japanese refineries. This was mainly due to falling efficiency of hydrocracker units. This long standing problem led the government to take several initiatives in the 1990s to improve the efficiency of these crackers. Still, the situation is such that Iran imports a great share of its fuel consumption, and engages in significant oil swaps with neighbouring countries to optimize oil qualities and infrastructure. For example, Mobil furnishes several million barrels a year to Iran from Turkmenistan, in exchange for comparable amounts in the other direction (MRST, IROST, and RITDS 2003). Currently, oil swaps are quietly being boosted with Russian and Central Asian producers. A recently constructed 300 km pipeline from Iran's Caspian port of Neka to the Tehran oil refinery allows Iran to triple its intake of Caspian crude and compensate producers with crude oil from the Persian Gulf. Without a significant increase in the refining capacity, oil swaps are expected to increase further.

An ambitious expansion in petrochemical production capacity and diversity was also undertaken. Twelve new projects were launched in the 1990's at a projected cost of 3.5 billion USD. This led to a seventeen fold surge in output from 0.8 million tons in 1989 to 13.2 million tons in 1999. The First Five Year Plan (1989 – 1994) helped to boost production of petrochemicals as indicated in table 3.1.

The Second Five Year Plan (1995-2000) continued the expansion and supported the growing importance of the objective of increasing exports of petrochemical products. Three out of five projects were expansions of the Bandar Imam Complex (TPA and PET, 6^{th} olefin, and MTBE). The remaining two were expansions of the Kharg Island and Isfahan complexes.

Current production of some 15 million tonnes per year is unevenly distributed across the 9 complexes run by subsidiaries of the National Petrochemical Company, and it is in particular notable that the Bandar Imam Petrochemical Complex alone accounts for 37% of this capacity.

Table 3. 1 Petrochemical projects under the First Five Year Plan[18]

No.	Projects	Capacity 1000t/y	Location
1	Isfahan Petrochemical	141,6	Isfahan
2	Arak Petrochemical (Phase 1 & 2)	669,7	Arak
3	Butachlor	17,5	Arak
4	Melamine Crystal	12	Urumiah
5	Bandar Imam Petrochem.	3752	Bandar Imam
6	Korassam Petrochemical	825	Bejnurd
7	Tabriz Petrochemical	288	Tabriz
8	Carbon Black	21	Ahwaz
9	Methanol	84	Shiraz
10	Di-Ammonium Phosphate	250	Mahshar

A production breakdown on main product areas for 2001 (most recent figures) shows the following pattern (from MRST, IROST and RITDS 2003).

Chemicals	3,1 mill. tonnes	25 %
Fertilizers	4,7 mill. tonnes	38%
Polymers	0,8 mill. tonnes	6%
Aromatics	1 mill. tonnes	8%
Fuel and hydrocarbons	2,9 mill. tonnes	23%

To boost both exports and production for the downstream industries, Iran has initiated a 20-year plan that includes some 30 new production complexes with a total capacity of 30 million tons per year.

Petrochemical industries, however, require enormous investments. They are heavily capital intensive with huge construction costs related to machinery and infrastructure. Knowledge flows are linked to technology-embedded in capital goods and the production process itself is know-how based and thus often linked to licences. Further, the industry is both R&D intensive and based on economies of scale. The capital and knowledge requirements are so demanding that Iran has turned to foreign multinational companies to supplement the government's own funds.

To better attract such investments, in 1998 the Iranian government established the ”Special Petrochemical Zone” or Petzone, a site of some 1700 hectares of highly integrated production facilities located on the border of the Bandar Imam Petrochemical Complex in the Persian Gulf. The zone allows for a special regulatory regime that provides incentives for foreign participation in joint ventures and various

[18] Plans are here meant as government periodic plans (typically 5 years) for investment and development, while projects are defined as specific entities of these plans as investments in given production facilities. Products are defined as intermediate or end products from petrochemical production.

tax and duty related exemptions[19]. The second special zone of South Pars has recently been established to allow the same conditions as in upstream oil and gas production. The mechanism of the special zones can be seen as a sign of the growing awareness on the part of the Iranian government of the shortcomings of the existing regulatory system. To be able to realize the ambitions laid down in the 20-year plan, these zones may even play the role of test-beds for regulatory changes to come.

During the 1970's and 80's protectionist policies stimulated the emergence of downstream industries that were potential users of upstream petrochemical products. According to UNIDO:

> For a long time, however, many of these downstream industries remained heavily dependent on imported inputs. The detergent, rubber, plastics, resins, paint formulation, PVC pipes and fittings, melamine ware, and textile industries in particular continued to import the bulk of their raw material needs until the early 1990's. The situation has changed dramatically since 1992, with the completion of the upstream projects … [the production of intermediate products from raw materials or feedstock such as natural gas] permitting a sharp reduction in the import of petrochemical raw materials for the downstream industry.

A notable pattern in the expansion of Iran's petrochemical technology and production, is the reliance on foreign licenses. As new complexes have been constructed, or new units in existing complexes have been added, the technologies have been mainly based on licence agreements with European and Japanese proprietors. Thus, it may be said that Iran has given priority to expansion of production capacities and output, while less attention has been given to domestic build up of technological know how and capabilities. Still, the technological competence base of the Iranian petrochemical industry was developed far better than that of the upstream oil and gas, for reasons alluded to above. And while the start-up phase of this industry was in fertilizers, Iran has pioneered a broadly based petrochemical sector since then.

While Iran's oil and gas reserves are vast and among the largest in the world (second only to Saudi Arabia), its domestic capability as an efficient and competitive producer of oil and gas is, however, less impressive, given that the recovery rate of its reservoirs stands at only 25%.

Iran is a major player in petrochemicals partly because of its gas reserves, but also because of the willingness to exploit this sector strategically to reduce dependence on imports, increase exports and develop down-stream industries. Hence, petrochemicals seem to have played a key role in the industrial expansion after the war with Iraq.

3.3 The Innovation System: Activities, Actors, Performance and Failures

As is the case with most oil exporting countries, the petroleum sector's contribution to the economy may be of a mixed nature. Fluctuations in the world market price for crude oil have led to dramatic changes in state revenues over the past 20 years. Such fluctuations in the value added cause serious disruptions in state revenues and reduce the ability to provide a consistent flow of services to the Iranian people.

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[19] See later sections on this development.

During the 1990s, the situation stabilised. Exports over 1990-1993 steadily rose, but revenues and value added fluctuated over the next ten years, though not as much as before. According to the OPEC, Iran’s contracted production capacity is about 3,75 million barrels per day, while 2 million of these are exported. Iran's crude oil is generally of good quality, ranging between 30-35 ASP. As heavy oil is not subject to OPEC quotas, there is a growing interest in developing these resources, and deposits of heavy and extra heavy oil (20-15 ASP) becomes financially more attractive, and the increasing growth of markets for natural gas and LNG will make gas all the more important in the future. Currently, Iran’s gas production capacity is 30 million cubic metres per day (cmd) of which 25 million are exported. The Iranian government has for some time promoted a policy to increase domestic consumption of gas to reduce oil consumption, so that during the period 1996-2001, annual average growth in gas consumption was more than 9% (MRST, IROST and RITDS 2003b).

The forward link from oil and gas, as well as products like ethane, gives the petrochemical sector a strategic role in the Iranian economy. Indeed, it should be seen as the crucial link between raw materials and end user industrial development. There is currently a long term strategy in place to increase natural gas and LNG as feedstock to the sector. In the third development plan, about 10 billion USD was invested to expand capacity, create joint ventures and invest in infrastructure. Production, export and especially domestic sale of petrochemical products have increased significantly over the past 6 years (table 3.2).

Table 3.2 Production, export, and domestic sale of petrochemical products 1996-2001[20]

Items	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Production (1000 tonnes)	10075	10817	11139	11002	11808	12543	13000
Export value (mill USD)	507	559	452	579	830	782	920
Domestic sale (bill. Rials)	2162	2767	3064	4388	5500	6035	na

Source: Ministry of Petroleum, MRST, IROST and RITDS 2003c.

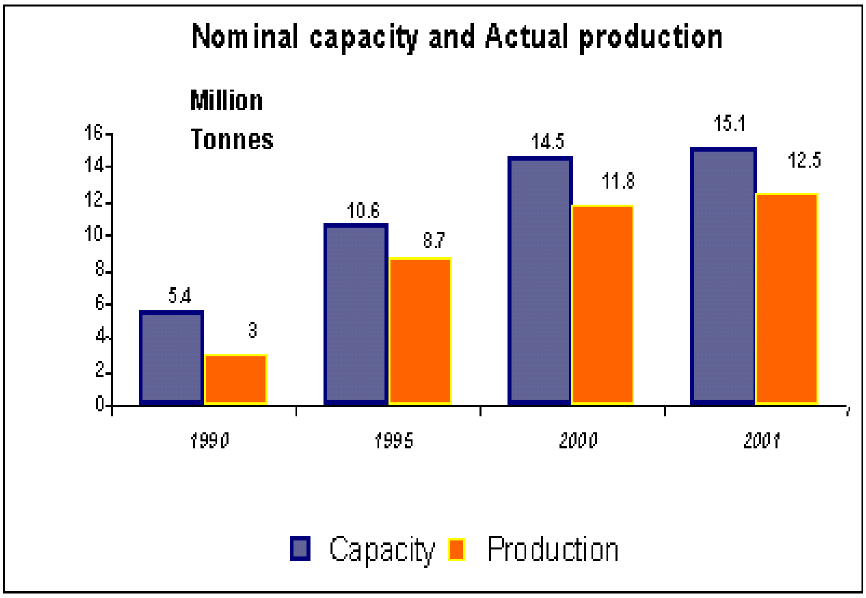
Figure 3.1 illustrates that production remains, on average, below capacity, partly due to plant shut downs for expansion projects and partly due to technological problems many of which resulted from the adoption of low quality equipment in the rapid build up and reconstruction that took place after the Iran-Iraq war.

Sectoral organisation

A striking feature of the Iranian system is that the upstream oil, gas and the petrochemical sector, as well as other commercial and research activities in petroleum related fields, are organised directly under the Ministry of Petroleum (MOP).

[20] The apparent drop in export prices and increase in domestic prices may be caused by currency changes in the period.

Figure 3.1 Capacity and production



Commercially oriented activities are organised as companies or divisions under the ministry, the most important being the NIOC (National Iranian Oil Company responsible for upstream exploration and production of oil and gas), NPC (National Petrochemical Company)[21], NIGC (National Iranian Gas Company), and NIOPDC (National Iranian Oil Refining and Distribution Company). Each of these companies or divisions have full strategic and operational responsibility in their respective field. In each, there are R&D directorates responsible for conducting research and development. In sum, the Iranian oil and petrochemical industries are organised as fully integrated public corporations directly under the MOP.

NPC currently owns nine production complexes each operated by a subsidiary company. Its overall annual production capacity reached 15.1 million tones in the year 2001. During this period, Kharg's sulphur granulation project came on stream to add a new capacity of 250,000 T/Y to NPC's total production. A substantial widening in the range of petrochemical products produced in Iran also took place over the 1990's, particularly in the development of aromatics.

The plants perform differently and produce for different markets, depending on the products being produced. For example, plants or complexes like Shiraz and Arak produce more than nominal capacity, probably explained by capital stretching. Others produce significantly less than capacity, often due to reconstruction or expansion projects. Further, complexes producing products like ammonia and urea are basically domestically oriented, while those producing higher value added products are more export oriented. This pattern seems to confirm an import substituting strategy in recent years, which was alluded to earlier.

[21] NPC became independent from NIOC only after 1979.

NIOC, R&D and the information failure

Prior to the revolution, the NIOC, which was founded in 1951, conducted most of its research outside Iran. This research was mainly geared towards increasing short term production capacity which in turn was harmful for the reservoirs. In other words, reservoirs were looked upon as given deposits to be extracted based on the technology and knowledge existing at the time of production start up. Foreign oil companies did little to alleviate this situation, protecting their knowledge to the extent that Iran was unable to build up domestic R&D capability in oil and gas.

After the revolution, this changed to some extent, and NIOC organised their build up of capabilities in two phases, initially within Iran and NIOC, then with partners/joint ventures. The directorate for R&D was established only in 2001.

NIOC's R&D activities are undertaken by in-house R&D units by subcontracting to the Research Institute for the Petroleum Industry (RIPI), established in 1959 as a subsidiary of NIOC outside Tehran, in the Petroleum University of Technology in Abadan and Tehran, and a number of other centres and more recently through co-operative R&D with foreign oil companies. NIOC itself has 8 specialised companies taking part in R&D. Currently, their domestic R&D priorities are in geo-science, reservoir engineering and enhanced recovery, drilling, health, safety and environment, and software. R&D activities are distributed as follows:

Table 3.3 Project areas

Project areas	**No. of projects**	**% of funding**
Geoscience	13	16
Reservoir engineering/ER	15	18
Drilling	14	17
HSE	22	27
Software	6	7
Others	12	15

The typical procedure in place to prioritise research is based on the articulation of needs or problem areas by the various companies and units within NIOC. Projects are prepared and submitted for funding to the Board of NIOC. NIOC annually allocates 1% of its budget to R&D. Resources not spent are by year end transferred to other purposes. The current fund for R&D amounts to 79 billion Rials. The main problem, however, is capacity. The NIOC system and related R&D centres in Iran are too few to absorb this flow of money, and the lack of capacity from earlier periods still exists. R&D policy in Iran moreover has not been able to orient the otherwise resourceful universities towards the needs of the upstream oil and gas activities. This is very different from the petrochemical industry where capacity is sufficient, though as will be shown, capabilities may be another matter. The visible bottleneck in this system has led to some compensating responses from NIOC, like initiatives to establish private R&D companies with incentives to university researchers to join them, and long term R&D projects to universities that includes training of Ph.D.s. Still, it is difficult to attract students, one reason being the fact that the only place these students can get employment after graduation, is NIOC itself.

The recent history of the Petroleum University of Technology illustrates the R&D capacity problem. Until 1998, the university did not have any applied petroleum related research. Research was instead general and academic, a left over from the period before the revolution where the presence of foreign oil companies and the proprietary nature of technological know-how did not allow such a build up. As this university is a subsidiary of the Ministry of Petroleum, the ministry decided in 1998 to revamp the institution by closing several of the general disciplines and opening new bachelors (Bsc) and masters (Msc) courses in oil, gas and drilling.

The Msc studies were launched in three areas: Drilling, reservoir engineering and production engineering. Other areas for research were opened up in centres outside the university, like strategic studies of the petroleum industry and polymer research. The Petroleum University of Technology currently produces 150-200 students yearly, a level that is not sufficient relative to the needs of the industry. To enhance capacity, the university has recently entered into agreements with the Herriot Watt University and Imperial College in UK, to provide student exchanges of between 300-500 students yearly. Currently, this university is the only institution offering higher education in the area of oil and gas, while 5-6 universities offer such studies in petrochemicals. This pattern is significantly different from that of other developing countries, such as Brazil, Venezuela, Mexico and Trinidad.

The lack of domestic capabilities in key areas of the oil and gas sector was also due to differences within the MOP over the priority assigned to petrochemicals, R & D, capacity and innovation in oil and gas. To a large extend, the production philosophy itself is a key source of the under-prioritization of oil and gas R&D. That philosophy grew out of earlier habits and practices focused on short term production maximization as opposed to long term production optimization and learning.

An integrated, governmental organisation

As in the case of NIOC and the oil and gas sector, the petrochemical sector is essentially organised as a company or division under the MOP. The mother company is the National Petrochemical Company (NPC). 53 companies are affiliated under NPC. Most of these are petrochemical production companies. NPC thus spans all activities in the petrochemical sector.

The products of NPC are broadly of five types:

A) Polymers
   1) Basic polymers
   2) Engineering polymers
   3) Rubbers

B) Chemicals
   1) Basic chemicals
   2) Intermediate products
   3) Inorganic chemicals

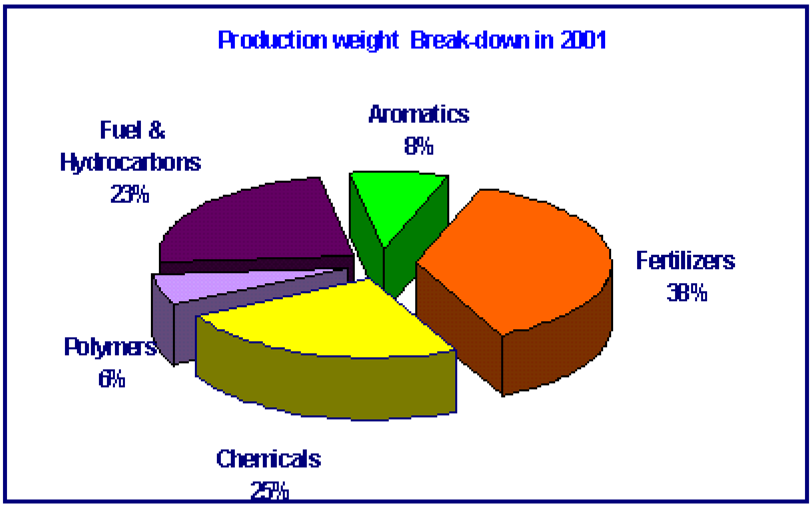
C) Aromatics

D) Fuels

E) Fertilizers and insecticides

The distribution of production across these product groups is shown in figure 3.2

Figure 3.2



The current build up of production capacity can be illustrated by the production of methanol, which recentlyl has emerged as a cleaner fuel in proton exchange membrane fuel cells, one of the promising new technologies in the reduction of pollution in the transport sector.

Total manpower in NPC was 16 600 at the end of 2001, a 3,4% increase over the previous year. R&D staff totals about 160 in the mother company, while many of the production complexes have their own staff conducting R&D. About 30% of the total staff have a Bsc degree or higher.

Bandar Imam Petrochemical Complex BIPC) and the PETZONE

While NPC is the mother company of 9 petrochemical complexes of various sizes, the most interesting of these is the Bandar Imam Petrochemical Company, which was badly damaged during the Iraq-Iran war. The reconstruction took place following the end of the war and in the period 1990-1994 several complex units came on stream.

The size and complexity of these facilities are vast, and illustrate that innovation in this sector is capital-intensive, volume oriented and long term. Currently, the feed stocks to this complex are:

a) 3.2 million tons per year of NLG from Khuzestan oil fields
b) 120 million standard cubic feet per day of natural gas from the gas network
c) 400 000 tons per year of salt, recovered from seawater
d) 1 million tons per year of naphtha from the Abadan Refinery
e) 182 000 tons per year of methanol from the Kharg Petrochemical Company
f) 7800 tons per year of styrene via import or from Tabriz Petrochemical Company
g) 71 000 tons per year of mixed Xylenes from import

Total production in the complex is over 7 million tons per year of which more than 4 million tons are final products. The quality of the products is generally high, with hydrogen an input into traditional and chemical processes as well as new wave technologies such as fuel cells.

To facilitate management, the production complex has been divided into five subsidiary companies of which two are service firms. Among these five, the Kimia company is of particular importance for the downstream automobile industry through the production of MTBE, a key additive in gasoline that enables the elimination of sulphur and hence contributes to a major reduction in pollution. The key backward linkage is to the sister company Faravaresh. The production of chlorine is based on the mercury process, but a decision was taken two years ago to change over to less polluting membrane technology.

The nature of innovation in these processes implies that it is often incremental and linked to a series of small and larger R&D and problem-solving projects that in sum represent an organisation of the learning curve. The optimal solution would in this case be for Kimia to have full strategic control over R&D resources. However, as will be discussed further below, the R&D department is subsumed directly under the general BIPC general management. As a consequence, R&D projects have to be proposed to the management for the BIPC unit to receive resources.

Companies in the BIPC complex are highly integrated, in terms of inputs and outputs. Currently they cover some 271 hectares, but the BIPC production system will gradually expand through integration with the nearby Petrochemical Special Economic Zone (Petzone). As a step in this direction the BIPC facilities are already connected by 21 pipe systems to the Petzone facilities.

The Petzone is adjacent to the BIPC and consists of some 2000 hectares of designated land. The Petzone was established in this area in 1997 due the advantageous location with BIPC and other geographical and natural resources. The aim "… was to make use of these advantages, with the incentives and opportunities created by the Special Economic Zone regulations in order to develop industries and trade both at the regional and international levels, especially petrochemicals and their down stream industries, absorb modern technology, create jobs and boost employment" (Petzone Brochure).

NPC owns, regulates and invests in the Petzone, and fully covers the costs of infrastructure. Among more obvious features like supply of raw materials, the Petzone offers in particular designated tax conditions for those in the zone, and hence duty free operation. In fact, the Petzone offers several specially designed advantages for industrial firms:

- All goods and machineries imported into the Zone for manufacturing or industries services, shall be exempt from the usual Iranian import-export regulations;
- A part of the goods produced in the Zone based on a share of the added value, may enter the country without restrictions;
- It is permitted to import and store the goods in the Zone without any restriction;
- It is permissible to issue invoices, and transfer all or parts of goods to other parties of the Zone;

- Investment in the industrial sector shall be exempted from taxes for a period of 4 to 8 years (Petzone Brochure).

The Petzone arrangement should be assessed in innovation terms as a valuable adaptation of the Iranian system. It does provide better conditions for the participation of foreign firms. Given the increasing need to bolster industrial activities through partnerships with foreign firms, the Petzone provides a good framework for joint ventures. Investments of foreign partners are more secure under the special Petzone regulations than in general in Iran. As no foreign firm can own land in Iran[22], joint ventures become the key to foreign investment.

For the Petzone to ensure its viability, innovation and wider contribution there is need to take into account two main issues: First, the regulations and strategies for the zone should be better aligned to innovation in order to contribute to the capacity building of domestic firms and research units. Second, the performance of the zone should be closely monitored to allow a future adaptation of the Iranian system at large.

3.4 Innovation Dynamics in the Petrochemical Sector: the Role of Buy-back Agreements

The history of foreign involvement in Iran's petroleum industry has been a contributing factor to the current policy on ownership and investment. Foreign companies are not allowed to take ownership in Iran's natural resources, including oil and gas. However, the 1987 Petroleum Law allows the conclusion of agreements between the Ministry of Petroleum and "local and foreign national persons and legal entities." Furthermore, the Iranian government initiated in 1995 a new institutional arrangement, or a set of contractual relations, considered to be a groundbreaking turn of events and paving the way for a new direction in the Iranian oil industry. In effect, the Iranian government is offering foreign companies three types of contracts in the oil and gas industry:

- Exploration contracts generally stipulate a minimum of scope and cost for exploration of a given area. The objective is to define oil prospects through drilling and seismic acquisition to a stage where a given oil prospect can be declared commercial. The contract is on a "no cure no pay" basis where the foreign company is reimbursed its investments only after reaching commerciality.

- Buy-back contracts are offered for the development of new oil or gas fields or the revamping of existing fields. They are arrangements in which the foreign oil companies funds all investments related to field development, including drilling and processing facilities, receives remuneration from NIOC in the form of an agreed production share over the first 5-7 years, then hand over operation of the field to NIOC after the contract is completed.

- EPC, or Engineering, Procurement and Construction contracts have been offered for smaller developments and have been used as a tool to divide contracts into manageable sizes so that local firms can participate.

[22] A foreign firm can lease land in the Petzone.

Since 1998, of the 42 buy-back projects offered to foreign oil companies, less than 15 have reached the final stage of negotiations. Without analyzing the innovation system in the oil and gas industry as a whole, the development of buy-back contracts represents a case of institutional design that warrants a broader assessment.

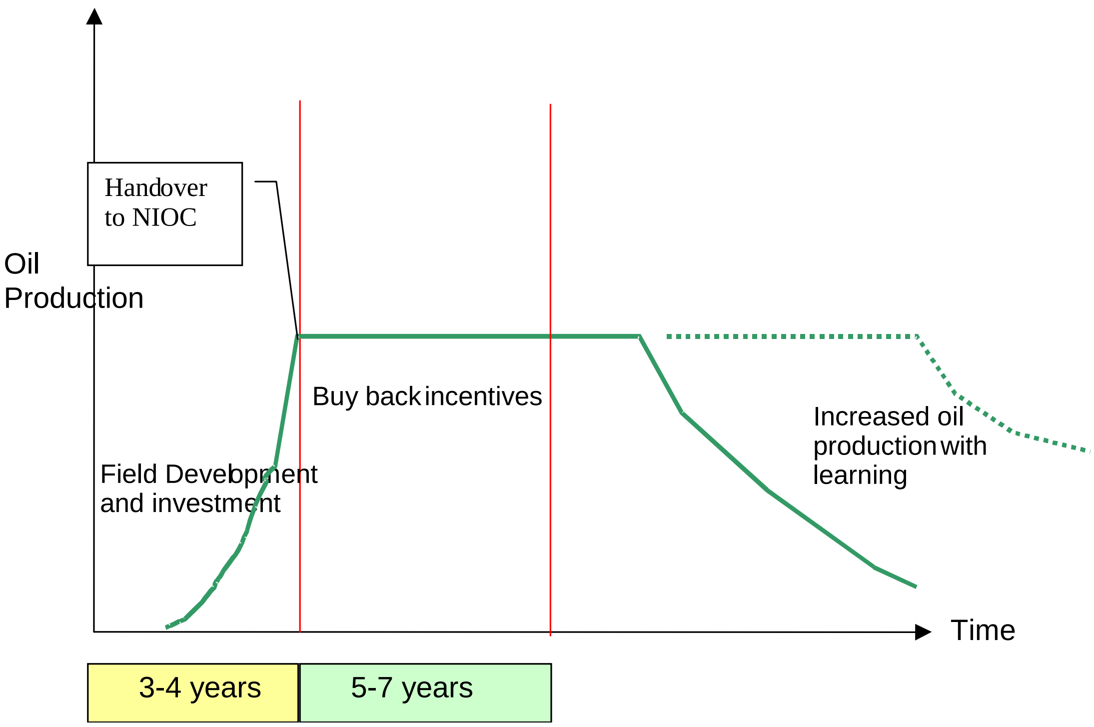
While the buy-back arrangements are being hailed as an institutional innovation, it is clear that they are quite deficient as an innovation policy instrument. Short-term Buyback contracts (5-7 years) offer no incentives for continuous field exploration or reservoir management, since activities beyond the exploration phase are done by others. There are no possibilities for the oil companies to book reserves as assets since no property rights are given to natural resources. There are no incentives for continuous field exploration beyond the exploration phase done by others. There are no inducements for technology and industrial development. There is little potential for changes and adaptations in the contract. The companies compete for these contracts basically on costs rather than capability for value creation on behalf of the Iranian government. And maybe most important of all, there is no concept of field development as a learning and innovation activity, the production model is fixed.

This leads to the problem of a lack of incentives to develop knowledge and technology that may enhance the recovery rate over time as the operator learns more about the reservoir, how it behaves, to better optimize the production profile. Reservoir management receives less focus, and the fields developed under this scheme tend to be sub-optimized both from an exploration and production point of view. This is illustrated in the Figure 3.3 below.

Hence, the short term focus coupled with reaching a contracted production level within a predefined period reduces innovation and a long term learning process to optimize recovery to the benefit of the Iranian people. This is linked to disincentives to share information. Both companies involved in exploration and production as well as NIOC itself have no obligation or incentive to share information, and the field development model chosen for the production phase is not chosen on the basis of best possible know-how for optimized reservoir management, but on the basis of partial information and a fixed model at the outset. Data on the reservoirs are normally distributed among different sections of NIOC, so that there is no transparent system of information storage, retrieval or exchange that could provide a platform on which to chose the best possible field development concept. The general consequence of this is a significantly reduced recovery rate from the fields and by implication a similar reduction of revenues for the government.

Embedded in the buy back contracts are arrangements for technology transfer and competence development. However, NIOC does not pay the same attention to the potential herein as to the costs of field development. Further, as stated above, there is no transparent information system that spurs competition and innovation for value creation of Iranian oil.

Fig. 3.3 Reservoir Management



Apparently, there are significant flaws in this system, and that there is a great need (1) to develop within the MOP or in an organization outside the MOP, or a Research institute, a transparent system of information (reservoir characteristics, production rates, pipeline capacity etc), allowing for competition among the companies to reach and deploy the best possible technology and development solutions, and (2) to redesign the institutional arrangement of the buy back contracts to include incentives for long term learning and innovation.

In early 2004, Iran introduced changes to the short-term buy-back arrangements, extending the period of such contracts from 5-7 years to as many as 25 years, while permitting the continues involvement of oil companies after the transfer of operation of the field to NIOC.

3.5 Licensing

The significant expansion of production capacity over the decade or so has been made possible by extensive licensing of technologies. These licenses stem from both American, European and Japanese sources. Over the years, the licensing has led to relatively little build up of domestic capacity in such areas as basic research, innovation-related R&D, basic engineering and product development capacities. Little attention was paid to this, while priority was given to enhancing production capacity and expanding products and grades in new units or through upgrading existing units.

Recently, efforts have been made to allow for joint ventures with foreign companies, a development that leads to improving the potential for transfer of know-how and build up of capacity. This build-up of capacity, as will be shown below, is taking place in NPC or MOP - affiliated organisations and less in the private sector. A specialised company or division in NPC, the Petrochemical Industrial Development Management Company (PIDMC), is responsible for contracting and licensing on behalf of NPC, while the contracts are then implemented by the petrochemical production company in question.

Licensing and the role of the engineering firm

One of the key issues in licensing practices is the extent to which they ensure build up of domestic know-how. Iranian engineering firms are increasingly able to contract for the engineering and construction work in the Iranian market. For example, Iranian engineering firms have been able to compete and participate in the expansion projects at the Bandar Imam Petrochemical Company. The experience and innovative behavior of one of them, Nargan company illustrates both the increasing strength of these companies, as well as the apparent lack of a R&D policy for the private sector.

Basic engineering, the most complex task and the one for which R&D and innovation activities are highly relevant, is mostly done by the foreign partner. Nargan’s recent response to this was embedded in a strategic choice to upgrade its technology and know-how, and decided to initiate the basic engineering as an internal project funded by internal resources (as operating costs, not R&D expenditures). The Nargan staff in this case did all the basic engineering, and benchmarked the result with the one coming from the joint venture partner contracted to do the basic engineering. There are two purposes for this: First to document for future clients and projects the capability of conducting the basic engineering, and second to upgrade the internal capabilities through an R&D project that could receive a quality assurance through the benchmarking with the results from the partner.

This example illustrates some important points about the petrochemical innovation system:

- NPC or the affiliated companies responsible for plant construction and contract management has no policy to stimulate private sector firms like Nargan in this case.
- There is little public support for Nargan’s internal R&D efforts.
- R&D efforts funded by NPC are typically conducted by R&D units internal in the NPC system or with universities related to NPC, a pattern that functions as a barrier to R&D build up in firms.
- Know how exists in Iran for many kinds of highly qualified work, but practice implies that such work be done by foreigners. Many licensors have their own network and will only provide the license information package to a select group of international firms.
- Nargan has no relations with RIPI or universities, suggesting poorly developed science-industry relations.

Other framework conditions are limiting the position that Iranian firms can take in such engineering work. For example, projects sometimes are funded by foreign governments’ aid programmes. Regulations governing these foreign funds require that 85% of the projects to be done by the foreign firm from the respective countries, while 15% be done by Iranian partners in the subsequent joint venture. Nargan has a strategic objective to exploit these projects, as even 15% are interesting given that these projects are often large. Still, this is yet another example systemic failures that creates disincentives and bottlenecks for Iranian firms to build up advanced capabilities.

3.6 Incremental Innovations and Learning

Petrochemical and oil refining industries are typically capital-intensive process industries where innovations are of utmost importance to generate effective learning, productivity and efficiency. Moving down the learning curve requires the companies to initiate and implement numerous small scale or incremental innovations over time. This is also the case in the Iranian petrochemical and refining industries. First, there is typically a benchmark oriented information system in place. This is constructed though a reporting system to the respective mother companies under MOP. This system supports the generation of learning curves through two means: First, through benchmarking the plants and their performance with their own recent history, typically three years; second, through benchmarking with other plants in the same sector. Normally, 73 items or yardsticks are used for this purpose, from energy intensity to measures of product quality.[23]

This is normally supported by organizational innovations. For example, the Shiraz oil refinery introduced the ISO 9000 system for the first time in 1997 to improve organizational matters and documentation of processes in the refinery. This was later followed by ISO 14000 on environment matters and ISO 18000 on health and safety. The Shiraz oil refinery has also been active in promoting initiative and motivation for daily improvements, and installed in 2001 a proposal system encouraging workers to engage in problem solving. A standing committee assesses proposals and issue a reward once a month. This has been followed up in other refineries. Such innovation practice is very important for the performance or productivity development of these facilities

3.7 The Organization and Role of R&D in Petrochemicals

Research and development is a key activity in the innovation system of petrochemicals. In fact, as was the case with NIOC, funding is not a pressing problem. Rather, the pressing problems relate to organization, manpower and prioritization, including the capability to govern R&D through a more market-pull or industrial perspective.

There are essentially four locations where R&D in the area of petrochemicals are conducted:

- Universities;
- Research Institute of the Petroleum Industry (RIPI);
- The Petrochemical Research and Technology Company;
- R&D departments internal to the petrochemical complexes.

[23] Even though this is a case of well developed information systems, it has till been impossible to get access to productivity figures for the sectors, a fact that reduces the potential in this analysis for international benchmarks.

As petrochemicals have been an industry of great priority for many years, 6 universities are engaged in teaching and research related to petrochemical activities. Much of this research is however, general or basic, and therefore less attuned to applied or industrial research needs. The universities participate in this system to some extent as the academic partner to the research and development activities organized within the sector itself, and has a capacity expanding function relative to perceived needs from this sector.

RIPI is the key player in R&D in petroleum related-fields, and cover both oil and gas as well as petrochemical and other areas. It is organized directly under the MOP as a division or company equaled to NIOC and NPC. It has a history of 40 years in research and development, and was originally established as a subsidiary to NIOC. Its mission is to help both solving petroleum industrial needs and expanding the industrial development of the country. It covers a wide set of activities, including:

- Exploration and evaluation of hydrocarbon and enhancement of oil recovery;
- Improvement and upgrading of petroleum products;
- Identification, evaluation and manufacturing of catalysts;
- Formulation and production of industrial lubricants;
- Synthesis and formulation of chemicals required by oil, gas, petrochemical and other industries;
- Development of techniques for gas refining and conversion to valuable products;
- Identification and fabrication of specialized polymers;
- Application of modern technologies in air and water pollution control and application of modern techniques in corrosion measurement and control for protection of industrial complexes;
- Design and development of modern industrial processes.

The institute has 728 staff distributed across 10 research divisions or research centres. The knowledge base measured by education is very good with 10 per cent and 42 per cent of staff having Ph.D and Msc degrees, respectively.

The Petrochemical Research and Technology Company is the in-house research center of NPC itself. There are currently three major objectives guiding the activities:

- Improvement of existing processes and acquisition of new technologies;
- Improvement of product quality;
- Supply of catalysts used at production facilities.

The current priority areas for conducting research programmes and projects are: environmental protection; corrosion; utilities and offsite; refractories and insulators; energy; packaging; and acquisition of new technologies. The Petroleum Research and Technology Company has more than 100 full time researchers and some 500 part time research staff, and participates in national and international R&D collaboration and partnerships.

Governance and prioritization of R&D

Based on the strategic planning of NPC, including new production facilities and expansion projects, R&D activities are deducted from the perceived needs arising from these plans. The Five-Year Plans are governed by the Parliament in terms of assessing their main objectives. For each area of priority in these plans, a team across the Petroleum Research and Technology Company and the commercial NPC companies (or their R&D departments) is established, leading essentially to a matrix structure within the NPC system. The detailed research projects are defined by these teams or groups within the priorities given by the strategic plans. However, depending on capacity and capabilities, these projects are then distributed among the 4 forms of R&D in the system according to the following general division of labour:

- Universities: Basic research
- RIPI: Mixed basic and applied research
- Research and technology company: Technological development
- In plant departments: Problem solving

This system includes a great number of pilot plants and contributions from the matrix set-up described above. If a given research project is seen as basic, it is usually outsourced to a university.

An activity labelled “custom-oriented R&D” (CORRD), has been set up to improve the custom orientation towards clients of commercial petrochemical plants. They have the following characteristics:

- They are linked to the commercial NPC companies;
- The commercial companies aims at identifying the need of their customers, based on information from these;
- The CORRD will co-ordinate this activity with other units in the structure depending on the problem;
- There are regular meetings between these customers and NPC representatives to facilitate the information exchange.

The dominating characteristic of this system is therefore technocratic. Priorities are defined according to the Five-Year Plans, and the selection process is based on proposals coming from the research staff. In effect, the system is a combination of bottom-up and top-down, but based on technocratic planning and less on performance targets. The link to the down stream or end user industries is essentially bureaucratic, whereby relationships are dominated by the plans and priorities set up by NPC.

To ease the prioritization to the benefit of these industries, a specific company has been set up, with shared ownership between the MOP and Ministry of Industry (50/50). The activities of this company (or rather inter-ministerial unit) can be summarised as follows:

- Policy studies and long-term identification of product development in NPC;
- Identification of the direction for production coming from the Ministry of Industry;

- Identification of needs of the private sector;
- Financial support of downstream projects partly through the banking system.

Hence, this system resembles the one above in its bureaucratic set-up and technocratic procedures for prioritization.

The Research and Technology Company (RTC) in NPC (including its plant level departments) have significant internal resources for R&D funding, and conducts parts of this itself. RIPI is then the main “clearinghouse” and resource centre for RTC in R&D capacity. In 2003, 300 projects were under way in the RTC system, 50% of which is done in house, the other 50% by RIPI and others.

The practical project prioritization and approval system is based on a council or board of directors, which includes the managing directors in NPC (of RTC, the petrochemical complexes, planning, production and logistics) as well as the managing director of NPC. While the selection criteria include a market orientation, the set-up will only indirectly include links with the end-user sectors.

This essentially bureaucratic system is mirrored on the level of plant R&D departments. For example, the Bandar Imam R&D department includes 17 staff, specialized in what has been most important for the Bandar Imam Petrochemical Complex (BIPC): Gas, basic polymers, catalysts and environmental technologies and research. With the current expansion of petrochemical activities in the area (ref. the Petzone), the R&D department will in the near future expand to 40 staff and new infrastructures. The allocation of R&D activities is done through budget centres, by which financial resources for projects are decided by the BIPC board.

However, there are plans in place to use more outside resources to better optimize R&D resources. The R&D centre may conduct research for other NPC companies. Hence, the bureaucratic system includes a division of labour and a strategy for specialization, even if the main mission of such a R&D department is to service the plant locally.

The BIPC R&D department does not conduct international R&D collaboration, but the staff participates in conferences and seminars with papers that are usually included in proceedings. In general, the BIPC R&D department publishes some 7-8 papers yearly in proceedings, and about 30 reports from projects. The latter are formal books, and all publications are overseen by the R&D manager. This means that most R&D is open, little is confidential (like development of catalysts that often take 4-5 years). The BIPC has put in place an incentive system for the staff to encourage publications that includes rewarding of 3 USD per page in project reports and 1,5 USD per page for translated papers from or to English. Hence, the incentive system reinforces the bureaucratic system in promoting R&D activities that results in academically relevant publications with less attention to business strategic value.

To ensure relevance of R&D conducted at the plant level, the R&D manager is usually recruited from an operational position. At BIPC, there are currently 200 small and large projects being carried out, including as much as 1500 people in various direct and indirect activities (university people, R&D staff, production works etc). In any project, the budget is topped by 5% of the allocation for human resources as a fee for external expert supervision.

The NPC with its operational affiliates invest great resources in R&D. R&D is seen as a key activity underpinning the long-term development of the sector. But the mode of organisation and prioritization is overwhelmingly internal, bureaucratic and planning-oriented, with a large proportion of R&D funds being allocated for basic research[24]. Less attention is given to success rates of projects or performance indicators steering the selection of R&D projects. The rules governing this system are highly inflexible, with the plans put in place often serving as rigid frameworks that are difficult to bypass or change. Essentially, the bureaucratic system is highly optimistic with regard to its managerial capability to govern a utility and demand-oriented R&D activity. The missing links in the system are performance-oriented evaluation and appraisal systems and target or performance-related criteria for project selection and eventual conclusion of projects. On the higher level, there is a clear missing link to the end-user industry as they are only indirectly involved and has few if any resources to support their R&D and development activities.

Although a different organisation, RIPI represents to a great extent the same system. Fourty years ago, RIPI was essentially a laboratory. Since then, its functions have been gradually extended to include R&D and technical services. Throughout most of the post revolution period, RIPI's research activity had followed a linear model, whereby incremental innovation is encouraged by investments in R&D. To some extent, this approach is linked to the fact that the petrochemical industry through its licensing practice has bought technology from foreign companies, with the effect that RIPI (and others) did not have to prioritize their R&D strategically.

More recently, this has changed. First, the technology transfer focus has been changed from the transfer of hardware technology and equipment to know-how with more focus on developing technological capabilities in RIPI. Second, RIPI engages more often in collaborative R&D, through, for example, joint ventures, whereby there are improved opportunities to exploit the knowledge base of a license since RIPI in such cases is a co-owner.

The priority setting and governance system in RIPI resembles that of NPC/RTC. The managing director is appointed directly by the Minister of Petroleum, who together with about 20 others, make up the governing council in the selection process. Within the context of one and five-year plans, projects not generated by NPC/RTC may be proposed for funding by the research staff and defended in this council. Referees are normally used in this process to ensure the quality of the proposal. In 2003, there were 26 research programmes in place in RIPI, all falling within the strategic plans. The corporate planning unit in the Ministry of Petroleum verifies each programme to ensure consistency with the strategic Five-Year Plan in place. However, the strategic plans do not contain selection criteria for programmes and projects, a fact that renders the process dependent on personal and collective judgements in the council. In other words, targets are not transparent and there is a lack of performance criteria in determining what should be achieved with the help of R&D.

[24] as much as 15% with support for Msc and Ph.D projects

Until a few years ago, RIPI was a subsidiary of NIOC. Its new affiliation directly under the ministry was motivated by the need to diversify its R&D activities and make them relevant to more than NIOC itself. While under the current funding scheme, 20-30 % of the project costs are covered by government and the rest by project funds. Over the next few years, the government's share will be eliminated and this should create more relevance in the priority setting. In other words, in the near future, the institute will have to generate funds for R&D from clients like NPC, NIOC or any other Iranian or foreign sources. What is not clear, is to what extent internal and external framework conditions can support the changes and adaptations necessary for the system to work effectively based on these new principles.

There are two evident challenges for RIPI in the years to come. First, there is a need to adapt the overly techno-bureaucratic governance of RIPI's activities, a governance system that is historically linked to the top-down planning regimes prevailing in the Iranian system at large. More specifically, there is a need to develop a mechanism that will help a more dynamic way to prioritize and allocate resources to future needs, for example user involvement, selection of processes driven by potential growth of end-user industries and the like.

Second, the research activities themselves need to be more interactive and less linear, taking into account that current and future R&D needs will have to be based on combinations of skills and knowledge bases. A related problem is the overly focus on engineering activities as part of the R&D, and an issue to be confronted in the future is the extent to which government R&D units should continue to conduct activities that could or even should be encouraged in the private sector.

3.8 Forward Linkages and End User Industries

A key motive for the importance given to the petrochemical sector has been its potential role in domestic industrial development. In fact, this is linked to the notion of the "distribution power" of an innovation system (David and Foray 1995), and its dynamism (OECD 2002): The more effective the innovation system is, the more it is able to ensure economy-wide distribution of knowledge flows and innovation. The key question here is to what extent and how the innovation system supports the demand-pull from end-user innovators and whether there are in place institutional mechanisms to bridge the gap between the producers of raw material and intermediates and end-user industries such as composite polymers and other high tech materials, rubber, textiles and others.

Figure 3.4 illustrates that approximately 30% of the production of petrochemicals is intermediate covering products that enter into the value chain, often in the same production complex. The rest is subsumed under final products being sold to clients outside the sector. With the increasing attention to more downstream-related product areas, the number of products in this sector has grown substantially over the past 10 years or so. However, the sector's forward linkages remain weak. Most domestic industries operate at half capacity, and several industries with as low as 20% capacity (Shaffaedin 2001).

There are attempts to increase the production of polymers to better satisfy some important end-user industries like plastics, but current information reveals that the capability of the sector to do this is still rather weak. For example, available research capability does not cover polymer engineering, only polymer science. Current production of polymers are therefore not sophisticated versions, but rather intermediates like polyethylene, PP, PVC. These are basic materials but not polymers as such. Table 3.4 illustrates the current situation.

Figure 3.4

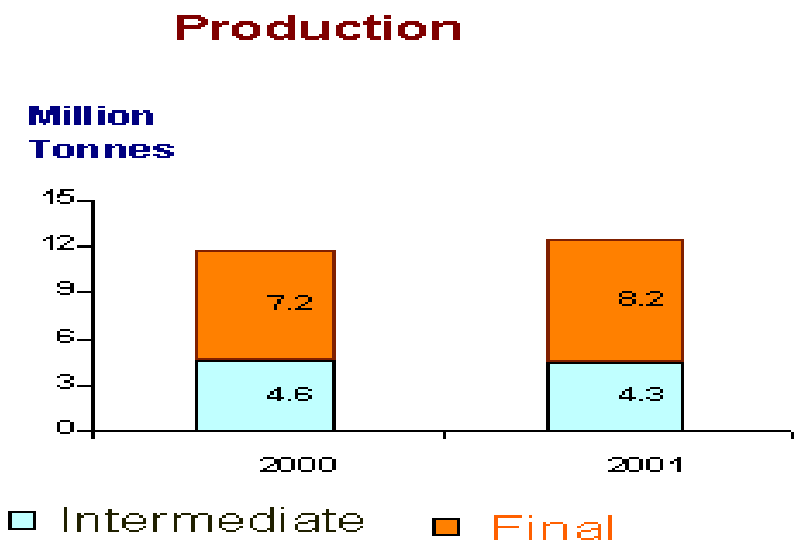


Table 3.4 Polymer capability

Types	Subtypes	Comments
Basic polymers	Resins Plastics Elastomers	Can be made Can do more Few grades: PBR, SBR, CR, NBR, all licenced from abroad
Sophisticated polymers	Composites Alloys	Not able to produce in Iran Not able to produce in Iran

This situation also questions the R&D capability in the sector, its priorities and linkages with downstream, end-user needs. This will be discussed later in the section. But the table points to the fact that too much of the research capabilities are linked to basic science and lab-oriented work and too little to industrially-oriented R&D, a possible systemic weakness in the overall petrochemical innovation system.

3.9 The Main Drivers of Innovation in Petroleum-Related Industries

A number of factors are likely to drive innovation in petroleum related industries in the years to come. Some of these are inherent in the Iranian and global economies and some will be influenced by politics. These will affect the shape and dynamics of the innovation system in this sector.

Increasing demand for petrochemical products

The demand for selected petrochemical products is likely to increase beyond supply over the next decade. Products like polyethylene and polypropylene as well as polymers are likely to see substantial increases in demand. Globally, demand is expected exceed capacity, a situation that will likely result in positive price developments. This is expected to take place in particular for advanced products like polymers (PET stands out as the most dynamic product).

Increasing wealth creation from oil and gas

The productivity in oil and gas, measured by recovery rates from the fields, have by and large been low, due to factors like war time necessities, too much short term focus and poor reservoir management. It is likely that attention to increasing efficiency and wealth creation from the oil and gas reserves will increase in the future. This will create a pressure for innovation in areas like drilling and reservoir management.

Increasing foreign interests in oil and gas

With its huge oil and natural gas reserves, Iran should be one of the most attractive destinations of foreign oil companies. Iran may benefit from this development through leveraging the contents of joint ventures and other agreements to bolster domestic build up of innovation capabilities.

Increasing need for industrial diversification and development

Oil, natural gas and petrochemicals today make up a significant part of the Iranian economy. These sectors are managed by state-owned companies. A key problem with this industrial structure is that there is a substantial dependency on revenues from oil and gas. These sectors alone are unable to meet the demands for employment creation in the Iranian economy. Hence, there is an increasing pressure to diversify the Iranian industrial structure, and create employment in industries where high-value production may take place. In other words, there is increasing attention to developing the forward linkages towards end-user industries and the technology and know-how need for domestic consumption and in particular export-oriented, dynamic products, some of which are outside the downstream product range from petrochemicals.

Environmental concerns

The combined effects of a very old car pool, low quality gasoline products and urban pollution is currently receiving greater attention as they both reduce the quality of life, represent waste of resources and tend to keep the auto industry locked in to old technology. There are changes underway, but the systemic and infrastructural nature of the problem indicates that concerted, long-term action is needed. Still, this environmental drive for innovation may be used to organise the public and private sector innovators in a broadly-based innovation strategy. A key issue is to what extent the innovation pattern will reinforce existing technologies and infrastructures or ensure a transformation to a future oriented sustainable system, possibly based on new fuel systems.

3.10 Main Findings: An Assessment of the Strengths and Weaknesses of the Petroleum-Related Innovation System

The analysis so far points to the important role of government policies without which an assessment of the innovation system will make little sense. The Iranian system is defined by the broader political-economic system, and changes in the innovation system as such without some broader changes in the surrounding political-economic system may have little effect. Hence, a critical weakness in the system, like lack of transparency, is very much a political issue, but has significant impacts on the performance of the innovation system. This was illustrated clearly in the case of upstream oil and gas, where lack of information, or better lack of shared information, creates a suboptimal situation in which the companies will not have incentives to bring out the best technology and knowledge, and where the necessary learning along the production curve will not take place.

In many developing countries, including Iran, exploration and production of oil and gas resources are conducted by government-owned corporations. This has been a highly legitimate way for governments to earn revenues from its oil and gas resources. But in the Iranian case, much of the oil rent is lost due to a missing link in the system: a government or state function that ensures that business players (be they private/foreign oil companies or NIOC itself) need to compete and develop knowledge to recover as much oil and gas as possible from the reservoirs.

The vast capital investments required to develop the petroleum and petrochemical industries provide ample reasons for the sector to be owned by government. But as the case of oil and gas shows, the key issue may not be whether the sector or firms are government or privately owned, but rather, in the former case, how the state performs and organises its functions. The high integration between the petrochemical business operations and the Ministry of Petroleum makes both strategic and operational decision-making political and bureaucratic rather than strategic and adaptive. Hence, even if the NPC will continue to be government-owned, much can be done to organise the company more independently from ministerial processes and hence separate political from business issues. This would help create a better and more adaptive environment for innovation processes in the sector.

Aside from these general or political-economic considerations, some points are noteworthy to highlight. Over time, a strong R&D capacity has been built up related to the petrochemical sector. This is a strength of the innovation system. Both within NPC (like in the Research and Technological Company) and outside in universities and research institutes, this capacity is large, and has apparently played an important role in the expansion of the petrochemical sector over the past decade or so. However, this particular system also has its weakness in terms of the way it is organised and the way research and development is prioritized.

The R&D activities are driven by the combination of strategic Five-Year Plans and individual proposals that do not ensure that research is geared towards the wider and long term needs of the Iranian downstream industries. It is evident that parts of the

R&D activity should be defined internally, but the large capacity in NPC and the sector as such is mirrored by a lack of capacity in the private sector, resulting in a skewed system where the main thrust of R&D is defined bureaucratically and to a lesser extent by a market orientation. For R&D activities to be relevant for NPC, the prioritization and selection mechanism could be more future-oriented and transparent, for example with clearer and more explicit selection criteria.

There is an apparent lack of dynamic science-industry relations, both in the university and research institutions. The private engineering firms have virtually no support for R&D activities, and little contact with public R&D institutions. Universities, even those linked to the petrochemical activities, tend to conduct research that is general and basic, and are less motivated to engage in R&D activities that are both more advanced and linked better to future industrial development needs, like sophisticated polymers.

Licensing has played a major role in the expansion of the petrochemical production through providing access to existing knowledge. The drive for rapid build up for the benefit of exports and import substitution and to satisfy the need for intermediate products of user industries, seems to have led to a lack of attention to building up domestic technological and knowledge capabilities. This is changing through more active use of joint ventures, whereby NPC and affiliates gain ownership to technologies and are able to build knowledge rather than importing technological equipment. It is vital that this development continues and even expands, but this also raises the issue of the wider organisation of R&D in Iran, as such activities tend to remain in the petrochemical, NPC- based sector.

3.11. Conclusions

The Iranian petrochemical sector has an enormous potential with its access to raw materials and a potentially large domestic market for products. The sector is well equipped with skilled manpower. There is an increasing demand worldwide for petrochemical products and there is a willingness in the Iranian government to continue investing and expanding the sector. However, unlike the production system, the innovation system has a number of deficiencies, many of which are linked to the way it is organised as a government business area. The sector is fraught with bureaucratic bottelnecks and has too few dynamic stimuli. The R&D activities are still too much oriented towards expansion rather than higher value-added production. Forward linkages to end user industries are weak and lack the resources and governmental support needed to flourish.

The current innovation system in oil and gas and petrochemicals is very much dominated by government and influenced by government operating habits and practices. These are largely centered on an innovation system that operates by command, that is by the formal and bureaucratic decision-making structures put in place to accommodate national or governmental control over the respective activities. This kind of government control renders the innovation system less strategic and adaptive than what the Iranian economy now requires.

Given the fact that more than 80% of the Iranian economy is government run, the conditions for the privately-owned industries are close to anemic. The system is in serious need of more dynamism, which has to be encouraged by a more market-pull in the overall system and a greater involvement of the private sector. This calls for more privatization, including activities hitherto organised under NPC, or creating independent public corporations that are regulated as private firms. The fact that conceptions of privatization as elitist concentrations of capital and power should not exclude developing a policy for a privatization and industrial development that ensures reduction in capital and power concentrations and more dynamism in a more market oriented system.

3.12 Main Recommendations

There is a critical need to separate government functions such as policy-making and resource management from production -- particularly in oil and gas and introduce greater flexibility and enhanced opportunities for demand-pulled linkages to the R&D sector. There is therefore a need to clarify and separate the various functions of government, that is the political or policy decisions from business decisions and thus create an institutional framework that is more innovation-friendly. In order to improve the innovation system in the petroleum and petrochemical industries, the Government may wish to consider the following recommendations:

Recommendation 1: Developing an Agency Function in Oil and Gas

The analysis in chapter three illustrates a number of signalling failures within the innovation system, particularly in the oil and gas sector. The issue at stake is the need for the innovation and production system to produce as much value from given oil and gas resources as possible, while making the best use of available knowledge resources to that end. This is not currently the case in Iran. From a system of innovation perspective, the failure to do so stems to a large extent from the fusion of functions: policy-making, resource management and production under the direct control of a single organization. What is needed is a clear separation between these key functions with the latter assuming an independent business planning and decision-making, or agency function similar to independent business units within a corporate structure. The two former have to be organized as government functions, the latter not necessarily so. The key point is the separation of functions and more independence. With regard to the policy-making and resource management functions, in the Iranian case, there is a need to organise a state function that currently does not exist. This is a public service organization that operates under governmental regulations to optimise the exploitation of oil and gas resources. An important function of such an organization is the provision of an information system so that development decisions can be taken on transparent, open premises. Such an organization puts pressure on NIOC, foreign companies and joint ventures to compete with their best available knowledge and technology.

The case of Norway is illustrative here. The Norwegian Petroleum Directorate (NPD) was established in 1972 in parallel with the state oil company Statoil. The task of NPD is to manage the oil and gas resources on behalf of the ministry of oil, which has the main responsibility for political issues and policy making, including setting the performance criteria for NPD. An important objective is to manage the resources and the oil companies in question to the maximum benefit for the Norwegian people through ensuring transparency.

Recomendation 2: Revising Buy-back Arrangements

The short-term buy-back contracts (5-7 years) were initially well received as a means to allow foreign oil companies to take part in Iranian oil and gas activities while providing capital without ownership of resources. This system of buy-back is far less than perfect, as it includes disincentives to learning, technology development and optimal recovery of reservoirs over time. There is therefore a pressing need to change this. There are two basic alternatives that both have the same aim: improving the benefits to the Iranian nation though better and more effective knowledge and technology transfer:

a) Granting of long-term buy-back contracts to as many as 25 years would be far more beneficial to the country as the foreign partner's interest in and capability of deploying long-term resources and R&D would be far greater. The likely result would be a higher oil recover rate and better opportunity for learning.

b) A more thorough or radical change would be to revise the contractual relationship between oil companies and the Iranian government. This could mean abandoning the buy-back arrangements altogether, and instead allow oil companies to take licensed ownership like in many other oil producing nations. This should not be confused with traditional ownership. Rather, the Iranian government will, and rightly so, see the oil and gas resources as the property of the Iranian people. But these resources are licensed with a view to their transformation into welfare, financial and industrial resources, preferably in the most innovative and efficient way. Licensed ownership thus means that a consortium of companies has the right to develop and produce oil and/or gas over the life time of the reservoir and will be induced to perform in desirable ways through normal regulatory and incentive policies. The Iranian government would ensure its stake through co-ownership and taxes. This would also imply a healthier distinction between the three governmental functions of owner, industrial actor and regulator. It would also ease the link between the exploration phase and the production phase, which is currently suffering from a systemic failure in providing disincentives to innovation and information sharing.

Recomendation 3: Reinforcing and Stimulating R&D Co-operation and capacity building in Exploration and Production

An important finding in this analysis has been the historical neglect of R&D capabilities for the oil and gas sector, partly caused by attitudes and actions of international oil companies in the pre-revolution period. The national capability today is far from what is desired compared to the vast and long term resources in Iran. The Iranian government should give priority to two basic strategies:

(a) There is a need to enhance R&D co-operation with foreign oil companies and research institutes as a strategic choice in the development of this sector. This could also be supported by institutional frameworks like the buy-back arrangements or be part of the requirements via a vis foreign oil companies. As illustrated earlier, the joint international research co-operation on improved oil recovery (IOR) with the Norwegian Statoil and SINTEF as a research partner. Although this programme has not been implemented as expected yet, it is still an example of technology and knowledge transfer that is more aimed at developing advanced Iranian capabilities than traditional technology transfer mechanisms. A strategy like this should include variety and dynamism, with a greater number of Iranian partners taking part in co-operations with a significant number of foreign partners. This will crate a broader stimulus and diversity in knowledge sourcing, and a longer-term capability on the Iranian side to monitor and exploit international knowledge and technology developments.

(b) There is a need to make universities and research institutes more responsive to the needs of the oil and gas sector. This includes developing teaching and research programmes in those areas where NIOC has current and future needs. Further, the governance of these universities should be adapted to include investment from co-operation with and influence from private and international companies. This would also help ensure that research and training efforts are guided with priorities that are future-oriented and oriented towards the application of new technology. In this context, the governance of the universities, like the Petroleum University of Technology, should be revised and be adapted to industry needs.

Recomendation 4: Encouraging Privatization in the Petrochemical Sector

The petrochemical sector is highly integrated within the NPC. Whether to privatise this sector, partly or wholly, is certainly a political decision. But if innovation and growth are to be given priority in future policies, then framework conditions that are conducive to innovation are warranted. Privatisation of activities, particularly those that are closest to the end-user industries, or represent service activities, would help create such conditions.

The objective is to create structures that are driven more by efficiency and innovation than what is typical of government or ministry owned public structures. This is linked to the wider need to a more specialised and transparent organisation of state functions. Some business activities are better organised privately, and a privatisation will support the development of the currently small private sector.

Recomendation 5: Developing Performance and Future-Oriented Prioritization and Selection Criteria for R&D

The current combined system of strategic five-year plans and bottom-up proposals from researchers is both inflexible and lacks strategic vision, even if the competence put in place to prioritize and select is high. The problem has more to do with the mechanism that is put in place than with people. For the petrochemical sector, there is need to develop a system that distinguishes between short-term needs for the sector and the long-term needs of advanced research needed to develop advanced polymers and forward linkages to the end-user industries. This includes the need to develop research programmes in co-operation with end-user representatives with performance or target-oriented objectives that also makes monitoring of R&D efforts more effective.

Recomendation 6: Reorganising the R&D Sector

Existing R&D activities are generally on an acceptable level, but not conducive to a dynamic innovation system. Such a system will contain independencies and incentives that gear those involved to organise their activities towards long-term industrial development. In particular, it is recommended that:

a) The Research Institute for the Petroleum Industry should be organised outside the Ministry of Petroleum, either as a public R&D institute under the Ministry of Science, Research and Technology, or as a specific semi-private research organisation, but publicly-funded, that could increasingly be base on collaboration with and investments from foreign and national companies. This would provide RIPI a short-term market funding and a more flexible and less sector-dependent position in Iran that facilitates both international cooperation and an orientation of R&D activities by stakeholders like key industrial innovators.
b) The role of the Research and Technology Company (RTC) in NPC should be reinforced, as the sector itself should conduct internal R&D for its own purposes. The current organisation seems rational as it facilitates co-operation and division of labour among the different units. However some changes are needed, most notably in setting priorities, which should be more demand and future-oriented. Similarly, incentives for research staff should be less on quantity and more on quality.
c) University capabilities are relatively better for the petrochemicals than for oil and gas. There is need to establish a funding mechanism that gives incentives for the universities to conduct research in areas that underpins industrial development. A flexible, programme-oriented system that includes strategic research in the universities should also be complemented with the development of effective arrangements for science-industry relations like co-funding of programmes, student projects, consortia development, Ph.D. programmes and exchange programmes.

CHAPTER 4. THE IRANIAN INNOVATION SYSTEM IN THE BIOPHARMACEUTICAL SECTOR

4.1 The Biopharmaceutical Innovation System: an Overview

The healthcare system has been a priority for the Iranian government. During the last several decades, Iran has achieved significant success in extending healthcare to the rural areas and in reducing the rates of infant mortality and population growth. Much of this success can be attributed to the availability and accessibility of medicines at affordable prices to the population.

Iran has a fairly well-developed pharmaceutical industry compared to others in the developing world. Its origins date back about 80 years to the establishment of the Razi Serum and the Razi Vaccine Production Research Institute in 1925 and the Pasteur Institute in 1920. Both institutes began by producing vaccines through traditional biotechnology methods, first for veterinary applications and subsequent for human use. Pharmaceutical companies in Iran started their operations by licensing the products and processes from the transnational corporations (TNCs) and manufacturing them locally. The operations mainly involved importing the raw material (bulk drugs) and formulating them locally. There were also TNCs operating locally.

The Revolution of 1979 was the 'first turning point' for the pharmaceutical industry in Iran. After the Revolution, the TNCs left Iran and subsequent political developments made it difficult to access technologies from abroad. At this point, all the pharmaceutical companies were nationalized. The subsequent Iran-Iraq War was a 'second turning point' for the pharmaceutical industry. During the War, acute shortages of drugs were experienced. This led the government to take a conscious policy decision to move towards the production of generic drugs.[25] The government invested large sums of money both in the companies and the research institutes to develop this capability.[26] However, with the exception of a few firms, pharmaceutical companies have not built up research and development (R&D) capabilities to develop new products and processes. At present, their technological capabilities are mainly in the areas of preparation of formulation and dosages. For the development of new products and processes, the firms depend on their linkages with local universities and research institutes.

The 'third turning point' for the pharmaceutical industry came with the launch of the First Five-Year Plan, which began in 1989, as a reconstruction plan after the end of the War with Iraq. This plan introduced the first steps towards privatization of the industry. The privatization policy is given additional impetus in the ongoing Third Five-Year Plan, which began in 2000. During the privatization process many of the companies were acquired by so called non-governmental organizations (NGOs),

[25] A product becomes generic if it was not patented in Iran

[26] According to a Report of the Ministry of Industries (1996) in 1996, there were eight private Industrial Research Centers and nine R&D units in industrial enterprises (including both private and public) in the pharmaceutical sector.

including religious charitable foundations or societies, such as insurance and pension funds. The National Social Security System is the major stakeholder. Today, about 35 to 40 percent of the pharmaceutical companies are owned by these NGOs.

Presently, the government continues to pursue a generic drugs approach. There is limited competition among companies and that competition is mainly based on product price. The kind of competition that stimulates innovation, however, is lacking. The government identifies a product to be produced and licenses the companies to manufacture it with production quotas placed on each firm. Multiple licensing is done in order to avoid dependence on a single supplier. These companies manufacture the product with the generic label. Drug prices are controlled by the government and the price of a drug is the same all over the country, whether it is sold by a private or public company. Consequently, the companies have no motivation to compete on brand name or quality.

The government subsidizes the companies in order to compensate for the low fixed prices. This also has implications for profit margins and R&D investments. Although no figures were provided, the subsidy element must be substantial, mainly because more than 70 percent of the raw material used in the manufacture of drugs is imported from Europe, China and India. The fixed prices of drugs may encourage firms to lower their cost of production through innovation in order to increase their profit margin. But, the government subsidies to the manufacturers to buy raw materials and production equipment reduce the motivation to innovate.

Thus, even after so many years of experience in drug production, the technological capability of Iranian pharmaceutical companies seems to be mainly limited to manufacturing and the development of new drug formulations. The processes, in most cases even the delivery systems, are developed by national research institutes and transferred to companies. The monitoring of new drugs launched in world markets, a process known as post market search (PMS), is also carried out by national research institutes. Once a product is identified, the government funds the development of that drug (mainly new processes and formulation). After developing the product, the research institute transfers the know-how to pharmaceutical companies on a royalty basis. Research and development carried out by companies is basically limited to the testing of product quality.

Under the Third Five-Year Plan, there has been a change in the government’s intervention. It is now less involved in strategy-setting at the firm-level and firms are encouraged to propose products for licensing based on their own perception of market need. However, it is not certain how this process works in practice since if one firm identifies a profitable product, others may seek a license for the same product. How this is to be arbitrated is not clear.

There are currently 55 pharmaceutical companies in Iran producing medicines, with 20 of them considered as large ones[27]. For a population of 60-65 million, this is not a large number. The market is fragmented among the companies in such a way that no

[27] There are 30 new applications for setting up pharmaceutical companies under the consideration of Ministry of Health (MOH: Interviews).

one dominates the market. As result, companies produce a wide range of products, probably in small volumes, without a therapeutic focus or specialization.

The total value of the drug market in Iran is estimated at USD 750 million. In terms of quantity/volume, Iran's local pharmaceutical industry supplies more than 97 percent of the market needs/demand. Only three percent of the drugs are imported. But, in terms of value, these imports account for nearly a third of the drug budget (MOH: Interviews). This situation opens up an opportunity for new companies to emerge to develop and/or to manufacture these high-value drugs. But, the price-cap on domestically produced drugs acts as a big barrier to entry. If the companies are allowed to reap the prices that are equivalent to imported price, small firms may license the product or develop a generic version locally and produce the drug. While it may not reduce the overall drug bill, it will reduce the outflow of valuable foreign exchange and reliance on imports.

The most prominent feature of the biopharmaceutical innovation system in Iran is the complete absence of operations by Transnational Corporations (TNCs). TNCs have no manufacturing or distribution facilities of their own in Iran. However, there are two types of collaboration between TNCs and local companies: The first, involves purchase and import of the whole formulation from the TNC by a local distributor (in this case a government agency). The second, involves importing the drug in bulk, repackaging it locally and marketing it with both TNC's and local company's names on the label. There are no significant learning opportunities in either of these approaches. But, the latter helps to reduce costs and to create local jobs. It also improves the availability of drugs.

Evolution of Modern Biotechnology Activities

Although efforts have been ongoing for a long time, modern biotech activities seem to have begun in Iran only since the early- to mid- 1990s. In 1975, the University of Tehran established the Biophysics and Biochemistry Research Institute. But, its biotechnological activities only began in 1981. The Biotechnological Research Centre of the State Organization for Industrial and Scientific Research started its activities in 1985, but only slowly moved to modern biotechnology activities.

The main thrust for modern biotechnology activities in Iran came with the establishment of the National Research Centre for Genetic Engineering and Biotechnology (NRCGEB) in 1987. Gradually, other national research institutes, such as Razi Vaccine and Serum Production Research Institute, Pasteur Institute, Institute for the Modification and Production of Saplings and Seeds, Pastures and Forest Research Institute, technical universities and the faculties of agricultural and medical sciences began to establish biotechnology departments and conduct research in biotechnology. In 1999, the Agricultural Biotechnology Research Institute was established (NRCGEB, July 2003).

The post-graduate training programmes in biotechnology were relatively slow to get underway. The first initiative came in 1990, when the Instructor Education University established a chemical engineering-biotechnology course at the Masters level and subsequently at the PhD level. Later the Pasteur Institute introduced PhD level courses in bio-products, in cooperation with the NRCGEB, the State Organization for

Scientific and Industrial Research, the Razi Vaccine and Serum Production Research Institute, and the Faculty of Health of the Tehran University of Medical Sciences. On the agricultural biotechnology side, the Faculty of Agriculture of Tehran University established a PhD level course on plant modification – molecular genetics and genetic engineering in 1994 and later in 1997 created a Masters level course in agricultural biotechnology. Later other universities such as Sharif University of Technology, Amir Kabir and Mashad universities also began to offer courses in biotechnology. In 1998, medical biotechnology was established as a specialized subject at Tehran University through the initiation of a PhD-level course (NRCGEB, July 2003). The establishment of courses also promoted collaboration among different academic and research institutes. This became evident also in the case studies carried out of the individual institutes.

By the early 1990s, a number of different organizations involved in biotech activities began to seek funding for research. To better coordinate activities and avoid duplication, in 1994 a Council for coordinating and assessing research proposals was established in the Bureau of Scientific and Industrial Studies of the Presidential Office. Earlier in 1989, the National Research Council was formed, which consisted of several specialized commissions. In 1996, the Biotechnology Commission was established as part of this establishment (NRCGEB, July 2003).

In 2000, following the directive of the President of Iran, the National Committee of Biotechnology was formed under the responsibility and authority of the Ministry of Science, Research and Technology (MSRT). This committee, composed of ministers, deans of universities and heads of the research centres, was given the task of organizing research and other activities related to biotechnology and preparing the national strategic plan for the development of biotechnology (NRCGEB, July 1996).

Herbal Medicine

Iran has a fairly well-established herbal medicine sector, although it does not seem to be as important as in India or China. The country has a vast variety of flora and so the government is placing importance on developing pharmaceuticals through herbal compounds.

The promotion and regulation of this sector comes under the MOH. Iran is one of the few developing countries to regulate herbal medicine. Since 1994, the government has regulated production in this sector to ensure that Good Manufacturing Practice (GMP) is followed. In the herbal sector, in the case of old or well-established products, the regulatory aspects apply only to safety and not to efficacy. But any new formulation, which is not prescribed in the ancient books, must have proof of efficacy. The MOH encourages entrepreneurs and assists them by organizing conferences of investors and scientists.

The MOH registers herbal products before they are launched in the market. Thus far, 150 herbal products have been registered. Compared to other countries, this is a relatively small number of products. But the MOH has gone farther than other countries in encouraging insurance companies to include herbal medicines among reimbursable items under health insurance plans. Herbal medicines, however, account for only four percent of the total drug market.

There are 32 companies manufacturing herbal medicines, mainly in oral and topical dosage forms (Cheraghali, Powerpoint presentation). Herbal products are of two types: i) Herbal extracts (mainly used by the cosmetics industry) and ii) Finished products (such as tablets and oils).

Among the companies producing herbal medicines, five have met GMP standards. These include GolDam, Barich, Darukpaksh, Soha and Zarband. Darukpaksh produces both modern drugs and herbal medicines. The firm is involved in the development of an anti-cancer drug based on herbal compounds identified through traditional knowledge and is collaborating with several universities to develop a new formula. Some local companies are working with French firms in herbal extracts and one large project involves a collaboration between Soha and the Red Crescent to develop pharmaceuticals through herbal extracts.

Many research institutes are engaged in isolating and identifying active ingredients from plant sources. The NRCGEB, for example, is doing research on medicinal plants that involves promoting the characteristics of a cell, i. e. culturing the ingredients rather than depending on the plants. Cell culture will solve the problems associated with standardization of plant-derived compounds. Since cell culture (like bacterial culture) does not involve plants, it can help in preserving species that are becoming extinct and this has implications for maintaining Iran's biodiversity. The research has so far shown promising results on a laboratory scale. Plant cell culture is not new knowledge. It has been attempted before, but was found to be economically not viable for commercial crops. In the case of medicinal plants, which are high value plants, however, it may prove to be profitable.

4.2 The Demand Side: Government Policies and Their Impact on Innovation in the Pharmaceutical Industry

From the biopharmaceutical industry perspective, the following governmental agencies are important: Ministry of Health (MOH), Ministry of Science, Research & Technology (MSRT), Ministry of Industry and Mines (MIM), Ministry of Jihad Agriculture (MJA), Technical Cooperation Office (TCO) in the Presidential Office and Ministry of Justice (for issues related to intellectual property rights - IPRs).

The MOH is the main agency for the promotion and regulation of the pharmaceutical industry, including biopharmaceuticals and herbal medicines. MOH's mission is "to provide access to sufficient quantity of safe, effective and high quality of drugs that are affordable for all the population" (Cheraghali, Report, August 2003). In order to achieve this mission, Iran adopted a full generic based drug system in its Drug Policy[28].

The main characteristics of the Iran national drug policy are (Cheraghali: 2003a):

- Fully generic-based drug system
- Local production of pharmaceuticals (promote national pharma companies)
- Price controls
- Formulation base national industry

[28] Generics are those on the WHO's list of generics as well as those products that are not patented in Iran.

- Herbal medicine industry
- Self sufficiency in vaccine production
- High regulation of the producers
- Licensing for locally-produced and imported pharmaceutical and biological products
- Active GMP inspection

The national drug policy reflects the import-substitution principle that is visible in the overall development of the biopharmaceutical industry.

Iran also has a national drug list based on generic names. The list is drawn up by the Iran Drug Selection Committee, which consists of medical specialists, pharmacists, pharmacologists, drug regulatory and national control authorities. The committee meets periodically to review and evaluate new drugs based on their generic identity, efficacy, safety and cost effectiveness. Once a new generic drug is identified, some companies are given licenses by MOH to produce that drug locally. The firms that have necessary innovation capabilities to develop processes and formulations produce the drug by themselves. But, most companies require the support of national research institutes or universities in developing products and processes.

In order to reduce the costs and improve affordability, the drug procurement process is centralized and a state-owned company is given the responsibility to procure most of the imported drugs. Two other semi-private companies have also been given some responsibility as alternatives. Only those drugs that are on the drug list may be imported. Price controls (price at which it is sold to the patient) also extend to imports. The volumes involved in these imported drugs are too low for local production.

More than 85 percent of the population is covered by medical insurance that reimburses expenditures for drugs. In order to keep drug prices low, the government subsidizes the production of essential drugs. These essential drugs are now available and affordable for more than 90 percent of the population (Cheraghali: 2003). As part of the changes introduced under the Third Five-year plan, which began in 2000, MOH announced a new policy of withdrawing subsidies from the industry and transferring them partly to public insurance companies (Cheraghali: 2003). Such a policy may encourage competition, provided that the companies are allowed to compete on brand names, and improve the quality of their products. Such a transfer will also reduce red tape and the potential for corruption associated with direct subsidies.

Government policy is, thus, stimulating the demand for innovation in generic drugs. But, in the allocation of product licenses, the capability of a firm to develop and produce a given drug does not appear to be a criterion. This is, perhaps, because the companies mainly rely on national research institutes for product and process related innovations in any case. As a result, companies are viewed not as innovators but as producers, having the capability to manufacture any type of drug, subject to the availability of the required equipment. As a consequence, companies have not developed any therapeutic specializations. It is also difficult to build substantive R&D capabilities in such general-purpose manufacturing companies.

In recent years, however, in order to promote therapeutic specialization among companies, the MOH has asked the companies to develop a ten-year plan within which they would identify a number of therapeutic areas for specialization. The registration of a new product by a company would then only be accepted if it falls within this 10-year plan. Otherwise, the company would be obliged to convince the authorities by changing the plan or it would pass on the product to another company that already has the relevant therapeutic area in its plan. Thus far, only a few companies have submitted such plans to the MOH (MOH: Interviews).

While the present policy works well to serve local health needs, it is not clear from existing policies whether the government is also actively seeking to build a competitive pharmaceutical industry. MOH, for example, says that it helps private sector firms to secure loans, but its main focus is on healthcare and it lacks the expertise needed to build up a competitive industrial sector. Similarly, a situation in which NGOs' own both pharmaceutical companies and insurance companies that provide health care coverage sets of a system characterized by contradictory incentives with regard to innovation. As insurance companies involved in the reimbursement of claims for drugs, the preference of these NGOs is to ensure that their clients have access to cheaper drugs. As owners of drug companies, their interest would thus lie less in undertaking the investments needed to produce newer and more expensive pharmaceutical products, than in providing lower cost drugs.

Ministry of Health

The MOH comprises *five* departments headed by deputy ministers: i) Research and Technology, ii) Education, iii) Logistics, iv) Food and Drug and v) Health. From a demand side perspective, the Food and Drug Department is the most important agency in the biopharmaceutical sector.

The Food and Drug department is the only supervisory board for the production and import of drugs in the country. Among its major duties, it issues permits for the release of drugs and pharmaceutical materials and equipment and supervises the performance of food and drug manufacturers.

The department consists of three directorates: i) Directorate of Pharmaceuticals – issues permits for the establishment of pharmaceutical firms, supervises manufacturing, carries out GMP inspections and ensures the registration of drugs (both small molecule and biologicals, and domestic and imported drugs); ii) Directorate of Food and Cosmetics – registration and inspection of both imports and domestic production; iii) National Controller (similar to the US Food and Drug Administration - FDA) – it has a testing laboratory to which the pharmaceutical directorate sends samples before a product can be registered. In addition, the Office of Rational Drug Use, which disseminates drug information to doctors and promotes rational use among doctors, patients and consumers is located within this department.

Standards Setting and Quality Control - From the demand side perspective, the regulatory, standards setting and quality control aspects are also important. Two government departments carry out these functions:

1) The Deputy of Food and Drug Department of the MOH for all the pharmaceutical-related industries.

2) National Standards Committee of Microbiology and Biology, State Department of Standards and Industrial Research - The official authority for determining, publishing and implementing official and national standards of the country for the biotechnology industry, excluding pharmaceutical-related sector. It helps in the improvement of production methods and the efficiencies of the industries and the increase of the quality of domestic production by researching and setting up of national committees. The national biology and microbiology committees have been set up in order to determine three standards: a) Biotechnology (the guide to the study of purity, biological activity and stability of products containing microorganisms), b) & c) Standards related to transgenic organisms and to their release into the environment (NRCGEB, July 2003).

4.3 Other Ministries Influencing Demand Side Factors

In addition to the MOH, the Ministry of Industry and Mines and the Ministry of Jihad Agriculture, also have influence in shaping demand for innovation in the (bio) pharmaceutical industry.

The pharmaceutical industry, like other industries must follow regulations set by the Ministry of Industry and Mines (MIM) with regard to the permits and licenses (e. g. industrial zoning, pollution control) need in order to set up manufacturing operations. Through such regulations, MIM is potentially able to influence the demand for innovation and stimulate technological capability building in the pharmaceutical sector. But, it has few policy instruments at its disposal to directly influence innovation, for example, to induce greater efficiency and lower prices, in the biopharmaceutical industry.

Biotechnology is a generic technology and its techniques can be applied in developing products for both human beings and animals. Thus the Ministry of Jihad Agriculture (MJA) can also influence the demand for innovation in medicines designed for human consumption through its role in shaping the demand for vaccines for the veterinary sector. This is clearly reflected in the case of Razi Institute, which, under the control of MJA, develops and produces vaccines and serum for both human and veterinary applications.

4.4 The Supply Side: Actors Promoting Innovation

From the supply side perspective, a number of organizations are active in promoting research and educational activities as well as in the promotion of innovation-based high tech industries in the biopharmaceutical sector. The main governmental agencies involved are: The Ministry of Health (MOH), The Ministry of Science, Research and Technology (MSRT), The Ministry of Industries and Mines (MIM), The Technical Cooperation Office (TCO) of the Presidential Office and The Ministry of Justice (for the Intellectual Property Rights).

Ministry of Health

From the supply side perspective, within the MOH, the Deputy of Research and Technology and the Deputy of Education play vital roles in promoting innovation:

a) The Deputy of Research and Technology

The Deputy of Research and Technology manages research in medical science, monitors research and technology developments, sets priorities among research projects and provides funding for projects. All funding goes to governmental organizations. Support to non-governmental research organizations or private medical universities (e.g. Azad University) does not exist at the moment. About 30 percent of the funding goes to basic research and the rest to applied research, for example, process development. It funds research projects in both the universities and the national research institutes.

The criteria adopted for the selection of research projects are: the burden of the disease, the result of needs assessments obtained through the population laboratories that collect information on health issues in each of the medical schools and existing capability.

The Deputy has also established a Cardio-vascular Research Centre and an Endocrinology and Metabolism Research Centre in the Tehran University of Medical Sciences. Another Endocrine Research Centre was established in the Shaheed Beheshti University of Medical Sciences. Even though these research centres are affiliated with the medical universities, they are provided separate budgets by the MOH, a practice similar to IROST and the MRST. These particular universities were selected as the location for the above research centres because they have built up expertise in these specializations through previous research in these areas.

The Deputy also formed three networks for basic research in order to promote coordination, exchange of knowledge and prevent duplication. These networks are: Medical Biotechnology Network, Molecular Medicine Network and Herbal Medicine Network. In general, there is no duplication of work, but in some cases the research requires meta analysis and parallel research in several laboratories.

b) The Deputy of Medical Education

This deputy is responsible for curriculum planning, teacher training and accreditation of medical schools. It also conducts the national examination for all students, including for those studying in private universities. It also conducts the examinations for super specialties and for approval of foreign degrees. In general, there is no shortage of doctors and specialists in Iran. However, shortage of doctors in some sub-specialties in some rural and urban areas is being experienced. There is an over supply of general practitioners and mid-wives.

Ministry of Science, Research and Technology

From the supply side perspective, the Ministry of Science, Research and Technology (MSRT) plays a key role in promoting research and educational activities in the biopharmaceutical sector. Even though, the responsibility for medical education was transferred to the Ministry of Health (MOH) in 1985, MSRT-affiliated research institutes are active in research and educational activities related to biopharmaceuticals, including herbal medicines. Prominent among these are the Iranian Organization for Research in Science and Technology (IROST) and the National Research Centre for Genetic Engineering and Biotechnology (NRCGEB).

The main responsibilities of the MSRT are:

- Goal-setting and policy-making for all levels of education and academic research;
- Comprehensive planning for the expansion of higher education and research for training skilful and specialized manpower;
- Supervision of universities and higher education institutes;
- Policy-making with regard to the establishment, expansion, merger and termination of any higher education and research institute;
- Policy-making with regard to overseas training for students, their support and supervision as well as their employment after returning to the country;
- Rule and procedure setting to deal with educational and research issues in universities and higher education and research institutes; and
- To propose Science & Technology policy to the Supreme Council of Science, Research and Technology (RITDS/IROST, June 2003).

Ministry of Industry and Mines (MIM)

The Department for High Technology Industries, also known as the High Tech Industries Centre (HTIC) is active in promoting research activities and in supporting the emergence of high tech firms.

The work of the Biotech Committee of MIM covers five sub-branches: medical, industrial, biomaterials, agro biotech and bioinformatics. From a global perspective, the Committee developed benchmarks in “industrial policy” (science and technology policy, laws & regulations, IPRs) and “international competitiveness”, through the analysis of policies in the United States, Europe and the Far East with respect to government funding for biotech research, targeting of biotechnology development, the regulatory environment, coordination between government and private agencies, policies targeting the improvement of industry-university relationships, coherence of policies such as taxes, rules etc. From a national perspective the Committee focuses on industrial policy, educational policy and promotional/protective policies such as domestic product tax exemptions or relaxation, foreign product tax increases, special funding policies.

The priorities in Medical Biotechnology are:

- Recombinant proteins production industry for biopharmaceuticals (vaccines, diagnostics, medicine),

- Advanced molecular diagnostic kits,
- Reagents required to promote biotech research in research institutes,
- Equipment required for production plants and research centres,
- Basic molecular biology services such as DNA sequencing and oligsynthesis.

These activities are not at the forefront of the technology developments, but they are something that Iran could immediately develop and produce for the benefit of the society and economy.

In order to achieve the objectives set out in their list of priorities, HITC envisages the following activities: using foreign experts; technology transfer; intellectual property protection; prioritize national biotech production; establish national strategy of medical biotech; facilitate Regulations & Rules relating to biotech export and raw material imports; develop private companies in biotech; relax or eliminate tax laws; promote and encourage joint ventures with foreign private & government sectors; protect national products; establish research centers and incubators next to the major universities; encourage foreign investment; and encourage scientists to establish private biotech start ups.

It not clear whether any priorities from among the list of priority areas have been fixed or milestones have been established within which to achieve the follow up activities in these priority areas. Many of these activities are still in the pipeline. Among the specific accomplishments in this sector thus far are: funding already established successful biotech companies such as Cinnagen; providing assistance in the establishment of new start ups (1-2 firms are being helped); suport for the creation of three biotech labs in three major universities in Tehran (Protein Engineering, Industrial Biotech and Biopolymers); Support for International Iranian Biotechnology Seminars; and promoting the establishment of a joint venture company between Iran and Germany (*Source*: Power Point Presentation).

Technical Cooperation Office (TCO)

The role of the TCO with regard to research, project development & funding and policy analysis and planning is best illustrated by its activities in the biosciences sector. TCO, currently, gives support to projects on a one-off basis. There is no strategic plan. Bioscience and advanced materials are TCO's currently most active areas (Interview: TCO, August 2003). The bioscience department includes five areas: agriculture (assays to screen and develop wheat and rice that is resistant to fungal infection), medicine, biopolymers (biodegradable cartilage made from chitosan extracted from shrimp in the Gulf, a joint project between the Polymer Institute of Iran and the Biomedical Research Centre of the University of Vienna), nutrition and environment (Interviews: TCO).

TCO planning and support activities in biosciences:

- Identifies and supports (building coalitions of partners, financing) new projects in both state and private sectors. TCO views its role as "end product oriented", that is, it supports projects that may result in a commercial technology/product,

- Supports technological capability building activities (by training Ph.D. students abroad, developing training courses and workshops in Iran and supporting R&D collaboration with scientists abroad).

Among the accomplishments of TCO so far are the following: (a) Publication of a bulletin to inform policy makers of recent bioscience findings and their economic utility. This has contributed to building a support base for biotech among policymakers; (b) TCO helped to move government thinking away from a ‘factory/production’ approach towards ‘knowledge and innovation’, building linkages between firms and university faculties so that local science is behind the transfer; (c) TCO has provided low interest loans to small biotech firms spinning off from existing biotech companies; (d) Created the Iran Biotech Website, to link researchers throughout the country and distribute the bulletin to them. Has also prepared four Electronic Workshops to link isolated researchers in the provinces with those in Teheran; and (e) TCO provided the idea to the Ministry of Health to establish 7-8 Centres of Excellence across the country and has identified a few such centres (TCO: Interviews).

TCO’s activities, however, have been ad hoc in nature, without any long term planning. In the future, they will need to be inserted into short-, medium- and long-term strategic plans, supported by a broader technological roadmap.

Ministry of Justice -Intellectual Property Rights (IPRs)

From the supply side perspective, protection of innovation (patents) and associated data (trade secrets), and appropriation of such innovation through commercialization (trademarks) play a vital role in innovation system.

In Iran, the law relating to patents and trademarks comes under the Ministry of Justice (Judiciary department). The department combines Patent and Trademarks Office and Registration of Companies and is headed by a Deputy Minister (who is also a Judge of the Supreme Court). The legislation relating to copyrights comes under the Ministry of Culture and Islamic Guidance.

Traditionally, IPRs were categorized as: i) Industrial Property, which is a Patent granted to an invention that has an industrial application; and ii) Artistic and Literary Works, which are granted Copyrights to confer moral and economic rights to the creators of such work. Subsequently, several other IPRs, such as trademarks, geographical indications, industrial designs, etc., have come into existence. The range of inventions for which these IPRs granted has also expanded (e. g. patents grants for biological substances, copyrights for software, etc.). Under the WTO’s TRIPS Agreements, even Trade Secrets are conferred a right to be protected.

The IPRs regime in a country has significant implications for innovation and learning. For instance, patents encourage inventions by granting exclusive commercial rights to the inventor and preventing others from imitating the invention. However, at the same time, a patent grant is subject to publication of the technical details of the invention. Such publication promotes subsequent waves of innovations. Similarly, trademarks protect the firms that have built up a reputation for quality of their products from cheap imitations. Such protection encourages firms to produce superior quality products through innovation. Apart from the patents, trademarks protection is also important for the biopharmaceutical industry.

Iran has a fairly well-established intellectual property system among developing countries. The first patent in Iran was granted as early as in 1925. The existing law on patents was enacted in 1931. In 1957, executive regulations were added and modifications made. A year later Iran became a Member State of the Paris Convention (on patents). In 1978, the Paris Convention text was revised. But, Iran joined the revised convention only in 1998.

Iran enacted legislation for copyright protection in 1969, but it did not join the Berne Convention (on copyrights). In 1980 & 2000, Iran enacted other laws to protect literary and artistic works. In 2001, Iran enacted legislation for software protection, which is said to be compatible with the International practices. A committee of experts from the legal and software sectors drafted the legislation. Under this legislation, if the software is a new invention, it can be granted a patent, otherwise it can apply for a copyright protection.

In 2000, the Legal Consultative Committee was appointed to revise the IP laws in Iran, as per the model law given by WIPO. This draft law, which includes protection for industrial designs and others, is placed in the Parliament for approval on a fast track (through ordinance). A year later, Iran became a Member of the World Intellectual Property Organization (WIPO). In August 2003, the Iranian Parliament approved two bills to acceding to Madrid Agreement & Its Protocols (trademarks). In September 2003, bills were to be submitted to the Parliament for accession to Patent Cooperation Treaty (PCT managed by WIPO) and to protect geographical indicators.

Currently, new legislation incorporating 16 different International Conventions on industrial property is being submitted to the Parliament. A High Coordination Committee composed of Deputy Ministers of relevant ministries as members revising the IP policies. These ministries include MSRT, Ministry of Culture and Islamic Guidance, Ministry of Industry, Ministry of Jihad Agriculture, PTT. Such legislation would help in providing stronger protection to intellectual property by incorporating enforcement as part of the legislation.

Data on patent application (Table 4.1) show active interest among non-residents in seeking patent protection in Iran. This may be reflection of the importance of Iranian market for inventors or assignee companies.

Table 4. 1 Data on the patent applications in Iran

	1998	1999	2000	2001	2002
Applications	496	543	616	993	1148
- residents	337	366	410	691	859
- non-res.	159	177	206	302	289
Registration	241	322	448	881	805
- residents	64	152	241	529	405
- non-res.	177	170	207	352	400

Source: Judiciary Department.

In awarding a patent, there is no substantive examination of the invention, other than publishing the material and asking for any objections from the public, i. e. only declarative. Publication is in the Farsi language. The time period from the application to the award is only one to three months.

Article 28 (3) of the Trademarks & Patent Registration Law Dated 1310 (1931) prohibits the award of patents to "Pharmaceutical formula or arrangement". It implies that product patents cannot be granted for pharmaceuticals.

Article 28 (2) prohibits patent protection to "A new invention, or the development of an existing invention harmful to public order, morals or public health". The law itself does not mention anything about the patentability of living organisms, so, biotech products obtained through genetic engineering are presumed to be patentable in Iran.

The law does not say anything about "compulsory licensing", presumably because a pharmaceutical company can market or manufacture a product only after a license from the MOH is given. Such licenses are normally given to more than one company.

Trademarks are registered for medicines. A separate law governing the pharmaceutical industry mandates that along with the brand name, the generic name of the product must be published on the package. In the case of food, drugs and cosmetics, if marketed in Iran, the generic name should be marked on the package.

Table 4.2 Data on trademark applications

	1998	1999	2000	2001	2002
Applications	6278	9494	10220	11082	12880
Registration	2528	3796	3750	4437	5187

Source: Judiciary Department

The legislation on patents and trademarks correspond to international regulations. But, the legislation on copyrights is different from the international norm. While it has a good standard for protection of national properties, protection to foreign artistic and literary works was previously considered as leading to cultural competition. This is now changing as government awareness of the importance of IPRs in attracting foreign direct investments (FDI) increases. Three seminars on Copyrights and International Conventions were held at the national level, in cooperation with WIPO and these have helped to create awareness in Parliament and the Guardian Council of the importance of protecting foreign properties. The Legal Consultative Committee has already prepared a draft law on copyrights[29] and the application to join WIPO, which was twice rejected by Parliament has now been approved.

There are now at least three different courses at the Masters level on IPR law in universities such as Tehran University and Shahid Behesthi University. Many students have started writing their theses on topics relating to IPRs. Although

[29] However, pending the approval of Parliament, foreign works are being protected under bilateral agreements on a reciprocal basis

awareness is slowly improving, SMEs as well as large firms in the biopharmaceutical sector have not been active in patenting.

4.5 Research and Innovation: Major Research and Training Centres

Biotechnology research in Iran mainly takes place in universities and research institutes, and to a limited extent in firms. Presently, more than twenty universities and reseach centers are involved in biotechnology research. It should, however, be noted here that there is no clear cut distinction between research, educational and production activities as several of the organizations perform all three activities. So, it is difficult to categorize many of these organizations as research institutes or universities or firms. Most of the research organizations also have pilot scale or full plants, supplying raw materials to drug manufacturers. Similarly, many of the major research organizations are involved with both pharmaceutical-related (for humans as well as veterinery application), agriculture-related and marine-biology-related research activities.

From an innovation system perspective, national research institutes, universities (mainly medical universities) and firms are the major actors in the Iranian biopharmaceutical sector. The role of support organizations, such as industry associations and venture capital firms is limited. In terms of financing for start-ups, private financing seems to be largely absent. In place of venture capital, governmental funds from HTIC in the MIM and the TCO, in the form of research grants and soft loans seem to be playing a critical role. Bank credit is also available for industrial operations. Even the government-owned development banks have not started venture capital operations or other low-risk financing mechanisms. The private sector business support and consultancy organizations, such as the Peyman Assistance, Consultation and Technology Transfer (PACTT) International Co., have just started emerging.

Two prominent actors that are absent in the Iranian biopharmaceutical innovation system are: i) the transnational corporations and ii) the contract research organizations (CROs), which carry out and manage multi-centre clinical trials.

Apart from the general medical and biotechnology research institutes/universities, Iran also has disease specific medical research organizations, such as Centre for Research & Training in Skin Diseases & Leprosy, Kerman Neuroscience Research Centre, Research Centre for Gastroenterology & Liver Diseases, etc.

From among the organizations active in the biopharmaceutical innovation system, case studies have been conducted to analyze organizational and innovative capabilities. The selected organizations are general purpose research organizations in (bio) pharmaceutical. They are not specilized in a specific disease or technique, but are considered by the government to be the most active in the field.

National Research Centre for Genetic Engineering and Biotechnology (NRCGEB)

The establishment of NRCGEB in 1987, under the supervision of MSRT, can be considered as the real entry of Iran into modern biotechnology field. It presently has 190 researchers, of which 31 have PhDs and 33 are Masters degree holders. The centre has a dual mandate of promoting research in the advanced areas of biological sciences and biotechnology and providing advanced training for scientists and students from other universities and academic institutions.

The centre's activities are focused on five major areas:

- Medical Biotechnology – i) Medical genetics (molecular diagnosis of genetic diseases, especially pre-natal diagnosis and identification of carriers of defective genes, determination of genomic diversity of communities and patients, gene therapy and genetic consultation); ii) Immunology (understanding the defense mechanisms of the body, new vaccines, designing serologic molecular diagnostic methods, increasing the level of body immunity and tissue and organ transplantation); and iii) Molecular medical pathology (understanding molecular mechanism of human pathological diseases such as cancer and infectious and parasitic diseases in order to find ways of diagnosing, preventing and curing).
- Plant Biotechnology – molecular mechanism of resistance to biotic and non-biotic stresses in plants; and molecular modification of plant species.
- Animal and Marine Biotechnology – patho-biology, reproduction and modification, and disease control of livestock and marine life.
- Industrial and Environmental Biotechnology - biomaterials for pharmaceutical, and other industries, isolate and identify microorganisms that produce biomaterials for industry and environmental protection.
- Basic Sciences - Biochemistry (to study structure and reactions between bio-molecules and engineer them for use in industries); Physiology-Pharmacology (effects of pharmaceutical and food products on cells and tissues of living organisms, particularly humans); and Bio-Informatics.

In these areas, the centre has 58 research projects underway, of which four are national projects. These include studies of genetic mutations among different ethnic groups of Iran, studies of multiple sclerosis and cloning the auto-antigen involved in the disease and other neurological diseases and construction of DNA vaccines vector for hepatitis B and C.

The centre offers long-term biotechnology education consisting of two PhD programs, one in Cellular and Molecular Biology, in collaboration with Razi University and the other in Molecular Genetics, in collaboration with Tarbiat Modarress University. About 20 students are presently pursuing their PhD at the centre.

The NRCGEB also collaborates with local universities in research activities. In its human genome diversity program, for example, the centre is collaborating with Tehran University of Medical Sciences and Terbiat Modarress University (some collaboration in complementary research). Similarly, to develop human growth hormone through transgenic goat milk, it is collaborating with Razi Institute.

NRCGEB became an affiliate of the ICGEB (International Centre for Genetic Engineering and Biotechnology- New Delhi and Triest), once Iran became full member of it. Now it can look forward to collaboration and exchange of staff with other members of ICGEB. The NRCGEB also received the Centre for Excellence Award given by the Third World Academy of Science.

A few years ago, when a decision was taken to set up a National Biotechnology Committee to coordinate national level planning and programs, NRCGEB became its Secretariat. The centre also serves as secretariat for the Iranian Genetic Society (500 members), Iranian Biotechnology Society (400 members) and National Bio-safety Committee (policy making and programming).

The staff of the NRCGEB has published over 50 articles in scientific journal and presented 350 papers at conferences. Its research has also resulted in products, which have been transferred to companies in Iran for commercialization. One of these is in human growth hormone (hGH) developed at NRCGEB and transferred to Samen Pharmaceutical Company for commercial production (see Box 4.1). A further 39 technologies are ready for transfer to potential users.

Biotechnology Centre (IROST)

The Biotechnology Centre of the Iranian Research Organization for Science and Technology (IROST) was established in 1980 with the following objectives:

- To provide a broad education and training in modern biotechnology relevant to the needs of industry with particular emphasis on bioprocessing, fermentation, healthcare, environmental monitoring and control, food and beverage, agriculture, energy and biochemicals;
- To provide particular integration with other institutions inside and outside the country.

The centre has 17 biotechnology researchers, of which 8 have PhDs and 9 are Masters degree holders.

The research activities of this centre are organized into five departments:

- Medical biotechnology - isolation of microorganisms producing anti-virus, anti-cancer substances, production of calcytonin hormone by cloning in the cell culture of potato, and laboratory production of cyclosporine;
- Environmental biotechnology - bio-elimination of vanadium, chrome, lead and paint from the industrial waste, and bio-remediation of sewage;
- Agricultural biotechnology - preparation of bio-fertilizers, production of lysine amino acid as food supplement for livestock and poultry, production of single cell protein from agricultural waste, using bacteria and fungi as microbial pesticides, etc.;
- Food biotechnology - laboratory production of the enzymes of the starch group including alpha amylase, glucose amylase and gluco isomearase and stabilizing them, isolation and purification of different enzymes, laboratory production of citric acid, etc.;
- Bio process engineering - manufacture of different fermenters, design and manufacture of the 150 liter distillation tower, manufacture of cell culture rooms, manufacture of vacuum dryers.

Box 4.1 NRCGEB develops the first recombinant product in Iran: Human Growth Hormone

For pharmaceutical purposes, Iran needs recombinant proteins, such as Insulin, Interferon and human growth hormone. Iran's annual import of human growth hormone alone exceeds USD 3.5 million and the demand is growing every year. So, Dr. Bahram Goliaei, the previous director of NRCGEB, proposed a research project to develop hGH, which was technically easier to develop than other recombinant proteins such as Insulin. As it was NRCGEB's first experience in developing a recombinant product, it chose a relatively less complex product. In addition to NRCGEB's own funds, the project received financial support from the MSRT and the MOH.

Human Growth Hormone (hGH) development by NRCGEB involved three phases:

Phase I involved separation of the gene vectors and their transfer to E.Coli (bacteria) for expression and gene sequencing for encoding hGH. This took ten people three years.

Phase II: included improvement of expression, start of fermentation in 5 liter fermenters, the purification process and quality control. This phase engaged 42 people with 25 PhDs. The director of NRCGEB was the head of this team.

Phase III: scaling up the process for 100 liter fermenters and improving the purification process to obtain pharmaceutical grade hGH. This phase took 2 years for 30 people. The product was manufactured on a pilot scale at the pilot plant of NRCGEB.

The completion of the project took much longer than anticipated and required more human resources, because NRCGEB lacked access to advanced instruments and therefore, much of the work had to be done manually.

Both product and process technology has now been successfully transferred to Samen Pharmaceutical Co. of Iran, which was introduced to NRCGEB by the MOH. Since the company did not have expertise in biologicals, the scientists from NRCGEB helped the company through continuous interaction. The company does not have fermenters, so NRCGEB will continue to supply the raw material. Samen will formulate and package the product. NRCGEB will receive a percentage of sales as royalties for 10 years. Samen's product has recently passed all the tests of the pharmacopia conducted in Britain.

Source: NRCGEB: Interviews, August 2003.

The centre has registered considerable success in its research efforts. Notable among these are: production of bio-fertilizer from sugar beet waste and pistachio peelings; production of lysine amino acid as a food supplement for livestock and poultry; use of different bacteria and fungi as microbial pesticides; isolation of azospirillum from the soil of different regions of Iran and assessment of its role in nitrogen stabilization, and isolation and production of biopolymers (see Box 4.2). It also produces antibiotics, such as penicillin G, streptomycin and erythromycin in its pilot plant.

Another noteworthy product developed by the institute is the B. thuringiensis MH-14 (bt-MH-14), a biopesticide for mosquito control. The project, supported by UNDP and UNESCO, has been successfully tested in different malaria infected regions. Its slow release mechanism has been effective in obtaining a control rate of 100 percent against malarial mosquito vectors, with no adverse impact on the environment.

The centre is working closely with the Persian Gulf Biotechnology Centre (PGBRC), Queshm Island, Iran, in marine biotechnology, biopolymers, the development of bone-implants from coral and the isolation and extraction of active pharmaceutical ingredients from marine resources. In collaboration with UNESCO and the Persian Gulf Biotechnology Centre, IROST is thus developing new fields of biotechnology - geobiology and geo-biotechnology.

In addition to its close working relationship with UNESCO and UNDP, IROST is a member of the World Federation of Culture Collection (WFCC) and collaborates with the Oceanography and Biotechnology Centre of Maryland, USA, Punjabi Molecular Biology Centre, Pakistan, Marmara Institute, Turkey, and the HEBEL Microbiology Institute, China.

Box 4.2 Isolation and Production of Water Absorbing Biopolymer by Biotechnology Centre (IROST)

The Biotechnology Centre of IROST has isolated and produced several biopolymers for the revival of saline and desert lands. Its water absorbing biopolymer was isolated and extracted from MH-1 bacteria present in Iran. This biopolymer has the following advantages:

- Absorption ability of 550-700 times its original weight
- Water retention time of one month in temperatures of up to 75° C
- Acts as a salt filter and stabilizes the soils surrounding the roots to be suitable for plant growth
- The polymer along with its accompanying cells act as water absorbing biological fertilizer which will not only fertilize the soil but also provide the required water for the plant
- It is non-toxic to humans, animals, soil microorganisms and environment
- Improves the fertility and porosity of the soil and enhances biological and natural metabolism of the soil.
- Production cost of USD 6.5 per kilo on a pilot scale

The biopolymer has now undergone field trials in different kinds of salty lands and valuable data has been obtained and may have significant potential in solving problems such as the recurring shortages of water around the world and the growing desertification of agricultural land.

Source: M. J. Azami, IROST, August 2003.

IROST also collaborates with industry in the transfer of technology. In its research on extremophiles (plants and microorganism that survive in extreme conditions) carried out in the Persian Gulf, it has extracted anti-cancer and anti-viral compounds. The efficacy of these molecules has been established and a cell line has been set up. With this technology, it has formed a joint venture with a French Company, Pierre Fabre, for further biological tests, scale up and manufacture. The scale up and manufacturing will be done in France. The centre and the French company will jointly own the patents.

Pasteur Institute of Iran

The Pasteur Institute of Iran was established in 1920 and is now under the Ministry of Health. The main mission of this institute is to carry out research and development on medical health issues, specifically on microbial infections and vaccine development. In addition to research and educational activities, the Pasteur Institute of Iran manufactures and markets pharmaceutical products, mainly vaccines and diagnostic kits much like a firm.

About 50 faculty members with PhDs and 120 graduate students are involved in research at the institute. Research is organized into three main groups: i) Microbiology Group - includes bacteriology, parasitology, mycology, rabies, virology, hepatitis, Aids, laboratory animals and microscopy departments; ii) Clinical Research Group - includes clinical research, pulmonary diseases research, epidemiology and vaccination departments; and iii) Biotechnology Group - includes the departments of biotechnology, molecular biology, biochemistry, immunology, physiology and pharmacology, pilot and cell bank.

The biotechnology department, established at the institute in 1993, was recognized as a Biotechnology Research Centre (BRC) by the Iranian Ministry of Health and Education in 1997. Since then, the center has expanded and reorganized into two units: i) Molecular Medicine and ii) Medical Biotechnology. The molecular medicine unit of BRC deals with molecular detection of prevalent genetic disorders and various infectious diseases in Iran. The medical biotechnology unit is involved in the development of recombinant vaccines and pharmaceutics (protein expressions, interferon and vaccine for H.pylori). The centre also offers services, such as protein characterization and gene expression. BRC is also the focal point of the National Network of Molecular Medicine and the National Network of Medical Biotechnology. The centre is also the National DNA and Vector Repository (Bank) and the National Reference Centre for Prenatal Diagnosis.

The Biotechnology Research Centre has 9 faculty members with PhDs, which is a rather small number. To achieve a critical mass of research activities and thus be in a position to make an impact, the number of senior researchers and the number of projects will have to be increased substantially. One of the ways to do this is through networking.

BRC thus actively seeks international collaboration in its research projects. With the Karolinska Institute of Sweden, for example, they are engaged in three collaborative projects: i) Heterogenity of HIV - study and compare the heterogenity of the populations of Iran and Sweden in terms of similarities and difference in drug resistance, and exchange of research data and personnel. This kind of work is also being done with the University of British Columbia, Vancouver, Canada; ii) Cancers related to Gastro Enterology; and iii) Malaria research - identification of mutations in drug resistance in plasmodium faliscum. The researchers from BRC spent some time at Karolinska and have published a number of papers.

These projects are jointly funded by the Iranian MOH and Sweden (SIDA/SAREC). In the development of a recombinant vaccine against *Leishmania, BRC* is sponsored by the TDR (WHO/World Bank/UNDP), in its research in the fields of Haemophilia and H.pylori, BRC has collaborated with well-known research groups in Italy and Denmark, respectively. BRC, in collaboration with the Centre for Genetic Engineering and Biotechnology (CIGB), Havana, Cuba, has worked on the industrial production of recombinant IFN-alpha, streptokinase, erythropoetin and hepatitis B vaccine. There is also scientific exchange between Pasteur Institute of Iran and Pasteur Institute of Paris and other worldwide network of Pasteur Institutes.

BRC considers these collaborations as mutually beneficial to the participants. For instance, the malaria researcher form BRC suggested a new methodology for the culture of plasmodium at Karolinska and at the same time, she learned more about the analysis of this part of the genome. Similarly, on HIV research it is collaborating with ICGEB, New Delhi, India. Presently, BRC sent a student to ICGEB. Usually collaboration involves the exchange of materials, knowledge, samples and data.

BRC’s research activities have so far resulted in: transfer of technology for manufacturing three recombinant products of alpha interferons, erythropoetin and streptokinase (in collaboration with Cuba), AIDS diagnostic kits and Recombinant gp63 as a candidate vaccine against Leishmania. Production of monoclonal antibodies for research and commercial purposes, development of IFN-gamma and recombinant proteins of H.pylori for vaccine purposes and development of ELISA diagnostic kits are in the pipeline.

The results of the research are passed on to the production unit for manufacturing. On the production side, it has six departments, such as virology (vaccines), antigens (diagnostics), biomedicine (BcG), animal laboratory, and quality control. It focuses on vaccines and biologicals. The production unit develops the delivery system and formulation (only injectables & diagnostics). Raw materials are mainly imported from India and China in the form of bulk drugs. It has in-house capacity to make bulk drug (active pharmaceutical ingredient) for BcG vaccine. It also produces vaccines for veterinary applications.

Razi Vaccine and Serum Production Research Institute

Razi Vaccine and Serum Production Research Institute was established in 1925 and comes under the Ministry of Jihad Agriculture (MJA). Like the Pasteur Institute of Iran, Razi combines education, research and production activities in one organization. The institute was founded to develop a vaccine against the deadly disease of Rinderpest, which at the time caused great casualties among cattle population in Iran. The institute accomplished the task in 1929 and since then it has been developing and manufacturing different vaccines and sera for human and veterinary use. Presently it produces 55 different kinds of biologicals and exports these products to 19 countries, including some in Europe. It has close collaboration with WHO and FAO.

The institute has a total staff of 1300 in its 28 departments and 5 branches in different cities of Iran. There are about 50 PhDs and 200 M.Sc graduates. It produces 3.5 billion doses of different vaccines. Its entire budget comes from the government, which varies depending on the level of production. So it is not operating as a commercial company. The budget may be cost plus profit, thus reducing the incentive to innovate.

Razi's main research and production activities are still dominated by conventional biotechnology methods. But, recently it has also embarked upon recombinant vaccines research activities. Biotechnology research at Razi is conducted in the following three areas: i) Production of new generation vaccines for livestock, poultry and human beings using genetic engineering methods; ii) Genetic diagnosis of poultry and livestock diseases; and iii) Production of transgenic animals.

The institue mainly imports the strain for research purposes, cultures it locally and then scales it up, after which dosage and formulation are developed and the product manufactured. In the production of anti-leishmania vaccine, for example, WHO provided the strain of the virus and the consultants to help in the construction of facilities as well as advise on product quality issues.

Razi institute also collaborates with institutes to which it supplies a strain. For example, it supplied a high yielding bacterial culture to the Berne Institute in Switzerland at its request. Razi's scientists then traveled to Switzerland to assist the Berne Institute in culturing the strain. In return, the Berne Institute helped Razi with equipment and facilities.

Among its notable achievements are: Production of a mumps vaccinal strain, which was patented and introduced to the world; production of a measles rubella vaccine; diagnosis and isolation of strains of foot and mouth disease virus using molecular methods; and design and manufacture of large fermenters for the production of vaccines for foot and mouth disease, aerobic and non-aerobic bacteria used for poultry and livestock and vaccines of diphtheria and human tetanus with domestic technology.

The core strength of Razi is in vaccine culture and production. Its major weaknesses are old equipment and lack of access to newer equipment from abroad because of the restrictions. It thus had to develop the fermenters themselves, wasting time and money.

Tehran University of Medical Sciences (TUMS)

Biotechnology research activities in TUMS are conducted in two faculties: the Faculty of Pharmacy and the Faculty of Medicine.

The Faculty of Pharmacy began its biotechnology activities in 1981 in a limited way by setting up a biotechnology laboratory. In 1994, a biotechnology department was set up within the faculty to partly meet the need for biotechnology drugs, in addition to conducting research. The department offers training programs to pharmacists in different areas of medicinal biotechnology. In 2000, a PhD program in medicinal biotechnology was established. The department consists of 4 PhDs and 6 Masters degree holders. So far 10 Masters and 4 PhD students have completed their theses in areas related to biotechnology.

Since 1994, the production of diagnostic kits and biochemical kits has been one of the important activities at the department. The main research activities have been focused on the production and purification of enzymes and determination of their characteristics. Presently, the expanded research activities include: i) Isolating and identifying microorganism that produce enzymes with industrial and medical applications; ii) Isolating and identifying microorganisms that produce antibiotics with wide ranges of anti-fungi and anti-bacterial effects; iii) biologically changing esteroids; iv) Producing recombinant proteins; and v) Recombinant pharmaceutical products.

The first product of the department was Interferon, which was developed in collaboration with an Italian research institute. The research on GCSF is completed and is presently undergoing clinical trials. Erythropoetin will be ready for production in another year.

The Faculty of Medicine is involved in research on genetics and immunology. This faculty has been a pioneer in genetic engineering in Iran. Among the most important of its research activities is the study of the nature and identity of molecules, pathology and the determination of mutations of beta ß-thalassemia in Iran for the production of related probes to use in prenatal diagnosis, and the application of genetic engineering and tissue culture techniques.

Medicinal and Aromatic Plants and Drug Research Institute, Shahid Beheshti University

The Medicinal and Aromatic Plants and Drug Research Institute was set up in 1998 at the Shahid Beheshti University as part of an agreement between MSRT and UNIDO. The mission of the institute is to undertake research and development, including pilot plant studies, related to the industrial processing and quality control of plant materials used by various industries in the preparation of pharmaceuticals, foods, cosmetics, perfumes and dyes and to evaluate the flora of Iran in order to contribute to rational exploitation of the plant resources and to a healthy development of these industries.

The institute has a staff of 10, with 3 PhDs and the rest Masters degree holders. It currently offers a Masters program on medicinal and aromatic plants. There are five students pursuing the program. The institute has six departments: Botany, Agriculture, Phytochemistry, Biological Activity, Process Technology, and Library and Information. Although the staff strength in the institute itself is quite small to be spread over six departments, it is enhanced by other members within the science faculty of the university who participate in the institute's research activities.

Its research programs fall into two broad areas: i) Basic research - investigating new plants from the medicinal families and isolate active ingredients; investigate traditional medicinal plants (e. g. hyprocumperfatum, an anti-depressant, investigate for properties such as anti-inflammatory and compare with other similar plants); semi-synthesize some compounds by changing the molecular structure and compare with the decimal for bio-activity. Its current work does not include research on using microorganisms to change compounds or transgenic plants; ii) Applied research - isolate active ingredients for anti-inflammatory anti-nociceptive effects from medicinal plants; separate anti-fungal and anti-bacterial and oxidant compounds through bioassay methods and introduce them in pharmaceuticals. At the moment it is not carrying out any cell culture.

Like other centers, the Medicinal and Aromatic Plants and Drug Research Institute actively collaborates with institutes abroad. Among these, it has collaborated with the Department of Chemistry, University of Rajasthan in India and Hokkaido University, Japan, in an anti-oxidant study that resulted in a joint publication and with the H. J. Research Institute, Karachi, Pakistan and the Plant Biology Department, University of Halle, Germany in another project. Typically, these collaborations involve sending samples for more analytical testing and when the data is returned, it is further analyzed at the institute in Iran. In the case of India, the partner had already isolated an active ingredient, which it sent to Iran for comparative analysis.

The institute does not have any collaboration with other institutes in Iran; but it collaborates actively with the local industry. For instance, Iranian drug companies send syrups or oils to the institute, which the institute analyzes for identification and analysis of bio-activity and compares them with the compounds used in Europe.

The institute has transferred technologies for 5 products to traditional medicine companies on a royalty payment basis. Among the products are: Licorice (glycyrrihiza glabra), which is a syrup for gastroenterology, and Cucurbita Pepo (common pumpkin) for prostrate disorder.

Iran has 60 different types of Salvia plants, of which only 2 or 3 are currently used in traditional medicine. The institute plans to investigate the other varieties. The institute receives funding from MOH, Ministry of Industries and MSRT.

Agricultural Biotechnology Research Institute of Iran (ABRII)

ABRII was the established in 1999 under the MJA. Prior to that, it was a department within the Institute for Modification and Production of Seeds and Saplings under the same ministry. Its objectives are: provision of food security for the country, quantitative and qualitative development of agriculture, and production of agricultural products without increasing the arable lands. Its total staff strength is 64, with 19 PhDs, 20 Masters and 25 Bachelor degree holders.

The research activities of the institute are carried out in six departments:

- Genomics Department - use of molecular markers for the study of the genetic diversity and characteristics of the germ plasma of plants, microorganisms and agricultural pests;
- Cell Culture and Gene Transfer Department - micro-propogation, plant tissue culture and transfer of useful genes into plants;
- Genetics and Cellular and Molecular Biology Department - genetics and growth of plants using cellular and molecular techniques;

- Microorganisms and Bio-Safety Department - microorganisms needed in the production of bio pesticides and bio fertilizers and the creation of a gene bank and establish principles in the area of bio-safety;
- Physiology, Biochemistry and Proteomics Department - identifying genes responsible for the plant resistance to environmental stresses;
- Technical Services and Research Support Department -

Among its research successes are:

- Production of a new variety of transgenic rice resistant to stem borers (presently undergoing field trials);
- Molecular location and breaking up of QTL for resistance to fusarium blight (jointly with the Tulln Agro-Biotechnology Institute of Austria);
- Production of bio fertilizers to provide nitrogen needed by the rice fields;
- Production of bio pesticides
- Production of a transgenic cotton plant resistant to diseases and pests
- Creation of varieties of wheat resistant to salinity.

The institutes' research activities do not involve recombinant technologies, but only gene transplant. In its gene screening methods it looks at the plant, not only at the physiological and morphological levels, but also at the protein level.

The institute collaborates closely with the International Rice Research Institute (IRRI), Manila, Philippines. Its scientists have been at the IRRI to work on salinity issues. Cooperation involves exchange of samples, visits and consultation and joint publications. The institute also collaborates with ICARDA of Syria on wheat salinity research. Its joint research project with Tulln Agro-Biotechnology Institute of Austria involved training, workshops, exchange of material from the gene banks and joint research proposals.

4.6 Research and Innovation: The Role of Firms

Among the firms that are most active in the biotechnology industry are: Razi Vaccine and Serum Production Research Institute and the Pasteur Institute of Iran (both unique and government-owned, mainly producing vaccines and diagnostic kits). Other firms active in biotechnology include Darupaksh, Dr. Abidi (conventional pharma firms), CinnaGen Company, Shim Enzyme Company (biopharma firms), Rana Agro-Industry Corporation, Sabzgolan Company, Rizafza Kesht Company and Tissue Culture Cooperative Company (agri-biotech companies) (NRCGEB, July 2003).

CinnaGen Company

Cinnagen was established in 1993, as a biopharmaceutical start-up company, with the objectives of providing necessary materials and facilities for the development of biotechnology and the production of molecular biology products. It began its operations by manufacturing restriction enzymes for local research institutes. Its activities are mainly in three areas: molecular biology, immunology and chemistry, but it manufactures over 50 biotech products such as restriction enzymes, blood group typing reagents and kits, various other diagnostic kits, including biochemistry, PCR and ELISA for infectious diseases as well as DNA-extraction kits.

The technologies used in the manufacture of restriction enzymes came from scientists working in national research institute, mainly the Pasteur Institute of Iran. Technologies for many diagnostic kits were imported, though the HIV-PCR kit was developed in-house. Technology relating to biochemistry kits was purchased from local research institute and was scaled up for production by the company. The company went into the manufacture of diagnostic kits for learning purposes and as a way of building up capacity. Its long-term focus is on biopharmaceuticals (e. g. peptides). Presently, it produces 15 different amino acids, which fall under the peptide category.

As part of its R&D activities, CinnaGen is developing a drug analog of GNRH hormone (bioserali), jointly with Russian scientists. Since the company already has the capacity to manufacture a synthetic peptide, it entered into this partnership in order to diversify into other products. As Boserali is imported as an API by Iranian pharmaceutical companies, a business opportunity exists for this high-value, low-volume API in Iran. CinnaGen's objective is to develop the best possible process from among those available. In this project, the company is also collaborating with the biochemistry department of the Pasteur Institute. CinnaGen does not have a synthetic lab, so it approached Pasteur with a proposal to develop the product in the latter's lab, together with Russian consultants. CinnaGen paid for the rent and reagents.

The company is also working with Cuban scientists to develop biotech products and collaborates with Razi Institute, Pasteur Institute and NRCGEB locally.

CinnaGen's annual turnover is USD one million and has a total staff strength of 60 people, mainly composed of technicians and employees on the production side. Much of its in-house work is on process development (scale up operations). It currently produces too many products without a therapeutic or a technology focus. For a small company product diversity is so vast that it is difficult to achieve scale economies or R&D focus.

Shim Enzyme Company

Shim Enzyme Company was established in 1995 for the production of specific raw materials such as enzymes, antigens and antibodies, as well as mass production of indicators and diagnostic laboratory kits.

The company has 7 scientists with PhD and Masters degrees. Its research focus is mainly on: Quality control of products, increasing the efficiency of the products and Stabilizing the products.

The company produces various kits and indicators including, enzymatic glucose, enzymatic trigliceride, enzymatic cholesterol, aspartat aminotransferase, alanine aminotransferase and alpha amylase.

4.7 Technological Capability and Innovation – An Assessment

Iran only entered the modern biotechnology era in the early 1990s, but within a short period of time, it has been able to build up significant capabilities. Much of this capability, however, remains in the research institutes. Pharmaceutical companies have the capability to formulate the drugs and determine the dosages and some are able to develop new drug delivery systems that improve the efficacy of the product. But, more than 70 percent of the raw materials, including the active pharmaceutical ingredients, are imported and process development is carried out by the research institutes, which then transfer the technologies to firms or produce the product themselves as Razi and Pasteur do.

Biotechnology products available in Iran are still mainly those produced through conventional biotechnology methods (e. g. vaccines and serums). Even in the agriculture sector, much of the work carried out is through tissue culture and plant breeding.

Among the modern biotechnology products manufactured are hormones, growth factors, alpha and gamma interferons, diagnostic kits and reagents. Among the most notable achievements are the development of human growth hormone and GM-CFS. Research is also being carried out to develop some vaccines against Leishmania and H.pylori. Some of these products are still in the development stage and may take a few more years before they can be introduced in the market.

In the development of the biotechnology sector, Iran took the correct step by initially focusing on the production of restriction enzymes needed for research and production purposes, and low-technology-intensive diagnostic kits. This step offers vast learning opportunities. Although these technologies are now available at a low cost worldwide, the complexity lies in adapting these diagnostic kits to suit the kind of strains of bacteria and virus common in Iran.

Basic research is focused on studying the gene mutations and diversity among different ethnic groups in Iran. Such research will help in the prevention of hereditary diseases and in designing effective drugs to treat the diseases.

Although biotechnology per se is a priority sector, most of the focus is on agriculture. An examination of the research institutes shows that almost all of them are involved in agriculture related research. The efforts being made in the biopharmaceutical sector is rather limited. The research groups involved in drug related research are small and the projects too few for a country the size of Iran.

In the agricultural sector, Iranian research institutes have been successful in developing disease resistant crops (e. g. a rice variety that is resistant to stem borers, and salinity resistant wheat) through modern biotechnology methods.

Iranian research institutes have also been successful in developing bio fertilizers and bio pesticides, although they are still undergoing field trials.

Among the techniques mastered by Iranian research institutes are the isolation, identification and purification of biologically active molecules/compounds from plants, microorganisms and marine resources. In this activity, Iran is very advanced and can help in building up an internationally competitive industry extracting active ingredients and developing products on this basis or even supplying these organic chemicals to world markets as raw material. In the medicinal plants sector, one research group in NRCGEB is working on a very advanced technique of cell culture (i.e. culturing the plant material like culturing bacteria). If successful, these technologies can help Iran establish a competitive industrial sector, as the world's demand for plant-derived compounds is growing.

Iran's Core Strengths

- Iran has a vast variety of flora and fauna and by using modern biotechnology techniques it can build a competitive industrial sector in the organic compounds sector.
- Iran also has a variety of different ethnic groups in the population and because of the prevalence of intra-community marriages among them, some of them have unique hereditary diseases. So, in a sense, Iran is forced to master modern biotechnology techniques to help treat its citizens. Such diverse population also helps in the clinical trials to prove the efficacy of the drug among different ethnic groups. This would also attract TNCs to carry out clinical trials in Iran and thus, Iran can integrate itself with the global drug discovery efforts.
- Biotechnology, including biopharmaceuticals and herbal medicines, is a priority sector for the government. So, the government is extending very good support in the form of research grants, subsidized loans and venture capital.

Weaknesses

- According to the 1999 report of the Biotechnology Commission of the State Scientific Research Council, Iran had 511 employees in the biotechnology sector, of which 361 researchers and 150 support staff. That amounts to less than one researcher per 100,000 people. It is not clear how many of these are in the biopharmaceutical sector, given the major focus on agriculture sector.
- Although, the research institutes claim that there is no shortage of scientists, an analysis of the staffing pattern shows that there are very few senior researchers with PhD degrees. It is these senior researchers who could initiate new projects and mobilize funding.
- The research projects relating to the biopharmaceutical sector are limited. More resources (people, money and projects) are needed to achieve critical mass. Even in Institutes with 20 to 30 senior researchers, only a small group of 5 or 6 work on medical biotechnology and that too in several research areas.
- At the moment, a long-term strategy to develop the biopharmaceutical sector is lacking. The selection of drugs to be developed and produced reflects an import-substitution strategy.
- At the firm-level or at the research institute-level, there is no focused approach on selected therapeutic areas. The companies produce a wide variety of drugs for all kinds of diseases. As a result, the companies lack specialized knowledge relating to specific diseases and cannot build upon this basis for research.

- There is limited competition among pharmaceutical companies, which is based on mainly on price. Added to this, subsidies to the industry and lack of brand-based competition act as de-motivating factors to innovation.
- Iranian research institutes have some problems in accessing equipment from abroad. This hinders research progress.
- Although, it is said that there is no duplication of projects, in the agriculture sector almost every institute is working on bio fertilizers, bio pesticides and single cell proteins. This is also the case with environmental biotechnology (e. g. Biotechnology Centre of IROST and NRCGEB).
- There is a lack of entrepreneurship among scientists, partly because of the lack of modern methods of financing that offer low risk capital to start-up firms.

Findings and implications for the pharmaceutical industry

- Government policy is presently not clear as to whether it seeks to build a competitive pharmaceutical industry or is content with the present situation, which serves the social purpose of making cheaper drugs.
- In order to build up a solid biopharmaceutical industry, a 'big push' is needed by the government through the provision of substantial research funding in the national research institutes and the provision of seed and venture capital funding to start-up firms. This would stimulate entrepreneurship among scientists.
- In some of developing countries, such as India, the government-owned commercial banks have started their own venture capital operations. Iranian banks could be encouraged to do like wise.
- From an innovation system perspective, the patients, who are the end users of the pharmaceutical products and the doctors, who prescribe these products have very little role to play in stimulating innovation. Permitting doctors to prescribe medicines on brand-name or patients to request branded products might motivate local firm's to innovate and further stimulate the medicinal plant industry as it seems to being doing in a number of small developing countries.
- In order to build up the biopharmaceutical sector, or for that matter the whole biotechnology sector, the government will need to adopt strategies of Technology Missions and Technological Roadmaps (strategies that have been successfully adopted by Japan, South Korea, Taiwan and even India), with clear long-term and short-term objectives and a plan.
- Iran should take advantage of the changing dynamics of the drug discovery process (where drug discovery is divided into smaller modules and each of these modules is outsourced). The Taiwanese have effectively done this. Iran can license a compound that has not yet undergone clinical trials and thus can be licensed more cheaply, for further development, clinical trials and manufacture, with exclusive marketing rights in the Middle-East and Western Asia. This would provide learning opportunities.
- At the moment, Iran does not have a Contract Research Organization (CRO), to conduct clinical trials and manage the data. Each of the hospitals has a small group that takes care of clinical trials. Promotion and establishment of CROs would help in attracting global drug firms to carry out trials in Iran and also help local firms to carry out multi-centre trials all over the country with

centralized control. A Contract Research Organization would also provide opportunities for learning.

- Current regulations require that any new drug being introduced in Iran will have to undergo clinical trials locally. But these trials are only to test for bio-availability and not efficacy. So, if the government wishes to move into contract research for clinical trials, it will have to establish protocols for different phases of the clinical trials and strengthen its regulatory bodies.

4.8 Conclusion

Advanced biotechnologies can offer interesting opportunities for the economic development of Iran, considering that biotechnology-based applications are not demanding in terms of capital investment or in requirements for raw materials, whereas they rely essentially on the availability of well-trained scientists and technicians. Iran can thus draw advantage from its appreciable human capital in the different scientific fields.

The different productive fields that are today developing very vigorously thanks to biotechnologies, and that can correspond to the interests of Iran, can be summarized as follow.

1) The health sector. The field is rapidly expanding world-wide and biotechnology-based diagnostics, vaccines and drugs offer very high added-value productions. Iran could enter profitably in this field, initially with generic products, since many important patents for such products have expired or are about to expire, and, conceivably, later, with novel products and processes more specific for the country and the region.

2) The agricultural sector. Over 100 millions of hectares are already cultivated world-wide with genetically engineered plants, and the resistance to their introduction is likely to subside in the near future thanks to the applications of rational safety regulation on the international scale. Many agricultural products typical of Iran can conceivably draw advantage from the application of these technologies, to reduce the damaged caused by pests, by high salt concentrations in the soil, or to improve the nutritional value, taste, etc.

In order to exploit these opportunities, it is highly advisable that Iran strengthens and expands its interactions with international centres of excellence, most notably the International Centre for Genetic Engineering and Biotechnology of Trieste (ICGEB) (including its New Delhi Component) that had already helped the country by: training scientists at the state-of-the-art level; organizing advanced courses in the country; funding advanced research projects developed by the NRCGB; transferring technologies for biotechnological vaccines and drugs to Iranian companies. Through such interactions, Iran will be able to draw advantage from the Inter-agency Co-operation Network for Biotechnology (that involves UNCTAD, UNIDO, UNDP, FAO, UNESCO, WIPO, UNU, etc) established at the Global Biotechnology Forum held in Concepción, Chile, in March 2004, which is co-ordinated by the Commission on Science and Technology of UNCTAD, and currently chaired by the ICGEB .

4.9 Main Recommendations

In building up technological capabilities in any sector, a key factor is the capacity to produce critical inputs and do so efficiently. In biotechnology, Iran has begun this process by producing the critical reagents needed for research locally. Iran's core strength lies in its human resources. Its scientists and engineers are well trained and many of them have studied abroad. Their knowledge of the subject can be comparable to the best in the world. In order to strengthen and build up a competitive innovation system in the biopharmaceutical industry, the Government may wish to consider the following recommendations:

Recomendation 1: Facilitate the Emergence of New Biopharmaceutical Firms and Competition

Presently, Iran has 55 pharmaceutical companies, less than one firm per million population. Each of these is producing a wide range of products for a variety of diseases. This situation discourages firms from specializing in some therapeutic areas and deepening their knowledge in those areas. The government should, therefore, promote the emergence of new pharmaceutical companies, with a focus on specific therapeutic areas from the inception.

While increasing the number of firms in the pharmaceutical sector is absolutely necessary, stimulating innovation will require the introduction of a healthy competition among them. The government should do away with its current licensing system and let the companies develop the products of their choice. If the government foresees a potential shortage of any drug, it can use the "compulsory licensing" system to compel companies to produce such a drug. The companies should be encouraged to compete on quality and brand name.

The existing system of subsidizing the industry has had negative impacts on both innovation and price and thus should be gradually removed. The savings can then be used as a demand side stimulus to extend better insurance coverage to the population. This would allow patients to choose the best quality medicine available in the market. The competition among companies would induce them to compete on quality and price.

However, in order to accomplish these, the intellectual property system should be strong both in legislation and in implementation. The pharmaceutical firms because of their R&D-intensity greatly depend on IPRs to protect their R&D investments. The existing legislation enacted in 1931 does not refer to issues such as compulsory licensing and does not clearly distinguish product and process patents. The new draft law is said to be a more comprehensive one.

Recommendation 2: Streamline R&D Incentive System

Over the past three years, the government has introduced a levy of one percent of the drug price as an R&D tax. These funds are used to provide R&D incentive to local companies. Although the government evaluates the proposed activities prior to granting an incentive, guidelines for what constitutes R&D activities and which such activities to prioritize within a national strategic plan have not been established. Much of the real research, moreover, still seems to be carried out by research institutes, so a similar incentive system for the researchers in these institutes, along the lines of the research granting council discussed above, would improve the productivity, quality and variety of research. As part of the incentive system, the scientists involved might also be given a share of the royalties, if their research results in commercially viable products or processes. This system is now being implemented in several developing countries, apart from the industrialized countries.

Recomendation 3: Facilitate The Emergence of Contract Research Organizations

"Clinical Trials" are among the most important and most expensive phases in drug discovery. Clinical trials are required not only for medicines, but also for diagnostic equipment and kits. As a result, independent "Contract Research Organizations (CROs)" have emerged to conduct clinical trials for the pharmaceutical companies on a subcontracting basis. CROs multi-centre clinical trials and manage the data coming from different test centres over the long duration of three to five years and provide feedback to the drug developer. Such CROs have also emerged in several developing countries as Transnational Corporations are increasingly seeking to conduct trials on different ethnic groups. The government should stimulate the emergence of such CROs in Iran. Presently, each hospital has a committee or a section managing the clinical trial data. These capabilities can be consolidated to create a CRO that can manage multi-centre trials all over Iran. Through CROs, Iran can integrate itself into global drug discovery efforts and gain from the learning opportunities they provide. It also opens opportunities for patients who have no hope of a cure with the existing drugs to try the latest drugs.

In order to set up CROs, the regulatory regime must be strengthened. International pharmaceutical companies will be attracted only if the clinical trial procedures, which are called Standard Operating Procedure (SOP), are in accordance with those approved by the FDA of USA or the European Regulatory Authorities.

Recomendation 4: Build up Critical Mass of Researchers and Research Programs

At the moment, the number of senior researchers (with PhDs) seems to be very limited in the field of medical biotechnology. Since the number of research projects is also small the shortage of personnel may not be obvious. But, for Iran to build a competitive biopharmaceutical industry, it should increase the resources (human as well as financial) devoted to the field by several times to build a critical mass of research and development activities.

Another option to quickly build up the critical mass would be to license a potential drug candidate from a firm abroad, before it has undergone clinical trials (since the drug is still in the development stage, it will be cheaper to license it), carry out the trials in Iran, develop the formulation, manufacture and market it in the entire Middle-East (exclusive marketing rights for the whole region should be negotiated with the licensor). Through this method, at least in the initial stages, Iran does not have to spend resources on uncertain, time consuming and expensive activity of finding the compound to treat a specific disease (target identification). Taiwan, province of China, is following this strategy, with exclusive marketing rights for whole of China.

Recomendation 5: Spin-off the Production Activities of Research Institutes into Independent Firms

The experiment of unique integrated research, education and production institutes (Razi and Pasteur Institutes) may have served a purpose in the past. Now, in order to build up a commercially viable pharmaceutical industry, their production activities may have to be spun-off as separate companies with a profit motive. At the moment, their production activities, i.e. manufacturing drugs, is done with the government budget (perhaps on cost + some margin basis, so no incentive to improve productivity or lower costs of production). The production levels are decided by the government and the budget is provided accordingly. These large organizations, which produce a major portion of the drugs required by Iran are not really companies and if there is competition in the industry, they are placed with an undue advantage over other private companies. So, the production activities of these organizations may be created as new companies to be run with earnings from the sale of products rather than government budget. Sale of these activities as separate companies to the scientists themselves will help the company retain its knowledge base and integrate it with the commercial realities. Such a spin-off will also give a thrust to the promotion of entrepreneurship in the country, which is sorely lacking presently.

Recomendation 6: Develop the Herbal Medicine Industry

Iranian researchers have been very active in the herbal medicine sector, particularly in identifying, isolating and extracting active ingredients. Such activity is also being carried out in the marine biotechnology area. Worldwide, there is a heavy demand for these herbal compounds. Some of these scientists, therefore, should be encouraged to form companies to extract and supply these inputs to pharmaceutical companies abroad. This requires the creation of venture capital firms, entrepreneurship training, and support in developing proper business strategies at the firm level.

Regulation of the traditional medicine industry that would require clinical tests for efficacy, toxicology, bio-availability as those for modern pharmaceuticals may help to promote this sector as an alternative to modern drugs. Such tests will also help in creating export markets for these drugs.

As part of the changing dynamics of the drug discovery process, specialized companies are emerging, that build up huge libraries of compounds and lease these libraries to drug companies for their screening activities (e. g. Affimatrix of USA). Although these companies have built up huge stocks of the structures of the compounds using the new technique of high through-put screening (HTPS), they do not do any screening against a target or testing themselves. Major pharmaceutical companies hire these compounds on a payment basis. Compared to the in-organic compounds, which are the basis of most such libraries, the compounds extracted from plant sources are said to contain more diversified variety of molecular structures. They are thus amenable to application of HTPS. Iran has a vast variety of flora and a study of these plants would provide thousands of molecular structures. Consolidating all the compounds identified (including future research) in different research institutes and building up libraries of such compounds could provide Iran with a unique business opportunity.

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